MODERN MECHANICAL ENGINEERING

A PRACTICAL TREATISE
WRITTEN BY SPECIALISTS

EDITED BY

A. H. GIBSON, D.Sc.
M.Inst.C.E., M.I.Mech.E.

AND

ALAN E. L. CHORLTON
C.B.E., M.Inst.C.E., M.I.Mech.E., M.I.E.E.

VOLUME I

THE GRESHAM PUBLISHING COMPANY LTD.
66 Chandos Street, Covent Garden, London

PREFACE

This work contains a general account of the art of mechanical engineering, which has for its object the harnessing of all natural powers for the service of man. So vast a subject cannot be described exhaustively in any single work of reasonable size. Selection must therefore be very carefully made. The principle of selection has been that of keeping the practical requirements of engineers as much as possible to the fore, leaving aside current speculation as to possible new sources of energy, new prime-movers, and so on.

Theoretical matters are discussed in their proper places, and an effort is made to present these subjects as concisely and clearly as possible to readers who are likely to be interested in them.

Volume I deals with the organization of a modern works, beginning with the Drawing Office and going through the Pattern Shop, Foundry, Machine Shop, to the Fitting and Erecting of the finished machine.

Volume II begins with a section on the Transport of Plant, a branch of the subject which deserves, but seldom receives, adequate treatment in books on Mechanical Engineering. This is followed by a section on Pipe-work, a subject of vital importance to operating engineers, as anyone who has had to operate a plant with a faulty pipe system must know. Then follow three sections on theoretical subjects: Applied Mechanics, Elasticity of Materials, and Properties of Materials.

Volume III deals with Fans, Pumps, Hydraulics, Water Turbines, and Refrigerating Plant.

In Volume IV will be found sections on Mechanism, Machine Drawing, Heat, and Steam Boilers.

Volume V is devoted mainly to Steam Engineering Plant,

and includes Coal- and Ash-handling Plant, Reciprocating-engines, Turbines, Condensing Plant, and an article on the Operation of Land Power Plants. In this last article the needs of power-station engineers have been kept more especially in view. This volume also contains a section on Engineering Chemistry.

Volume VI is devoted to Internal-combustion Engines, and deals with Gas-engines, Oil-engines, Motor-cars, Aero-engines, Gas-producers, the Operation of Oil-engines, and the Operation of Gas-engines.

THE EDITORS.

CONTENTS

VOLUME I

DRAWING-OFFICE ORGANIZATION

By GEO. W. THOMSON

PATTERN-MAKING

By JOSEPH HORNER, A.M.I.Mech.E.

FOUNDRY WORK

By JOSEPH HORNER, A.M.I.Mech.E.

THE MACHINE-SHOP

By JOSEPH HORNER, A.M.I.Mech.E.

FITTING AND ERECTING OF HEAVY MACHINERY

By G. M. S. SICHEL, B.Sc.

DRAWING-OFFICE ORGANIZATION

BY

GEO. W. THOMSON
Editor of "The Draughtsman"

Drawing-office Organization

Introduction

The draughtsman and his work form an essential link in the chain of any engineering organization. He not only indicates the finished article desired, but largely the routine and progress of the work, and his drawing is, in effect, a series of directions as to how the work is to be done. When the drawings or order sheets leave his hands, the method of distribution is so arranged that they shall go to the various shops and yards in a certain definite order and time, so that there shall be no hitch, neither forgetfulness nor overlapping, and if possible some system of checks is introduced, so that, where forgetfulness may on occasion take place, the omission can be made good with the minimum loss of time and cost.

There is a tendency on the part of some to regard drawing-office work, and, in a lesser degree, pattern-shop work, as unproductive labour. This argument, if true, would require to be logically extended until we came to the fact that, as all machinery was only a means to an end, the making of machines themselves was unproductive. But employers would be very unwise if such crude materialism were allowed to interfere with good and even elaborate staff work, as it is in the initial stages of design that the largest ultimate economies can be effected. The best firms realize this, and neither stint staff nor equipment, and make large allowances for experiment, research, design, and administration.

It is necessary, therefore, to consider very carefully the detailed organization of the drawing office, and the routine to be observed from the time the work enters as an estimate or a contract until its final dispatch, for the work of the drawing office is not completed with the issue of the drawings to the shops. An endeavour will be made in the following pages to portray a form of up-to-date organization which, if carried out and possibly extended to suit particular circumstances, will enable a firm to compete successfully against less efficiently organized rivals.

CHAPTER I

The Estimating and Costing Offices

Costing System.—Large modern businesses keep the estimating department distinct from both the design and working drawing offices, but, of course, with absolutely free access to the working drawings, sketches, orders, and data-books of the drawing office, and with access to the books of the costing department. The costing department is sometimes run as a branch of the estimating department. A good costing system is the foundation stone of successful estimating. To neglect this important section—and it is shamefully neglected in all but comparatively few firms—is to run very serious and quite unnecessary risks. The working of this section would demand a monograph on itself to describe it: it is taken for granted here.

Scanty Material for First Estimates.—In estimating for new contracts, one is usually given only a few general outlines in the first case; indeed, there may be three or four tentative offers before the definite contract is fixed. This is very noticeable in large ship contracts, where the shipowners have to study carefully a great number of problems before coming to a definite decision, such as the quantity and kind of trade anticipated, dock accommodation, fuelling facilities on the proposed route, repairing facilities, tides, and consequently most economical speeds, &c. Many tentative schemes must be submitted, and it may take months before a satisfactory conclusion is reached.

This sort of thing makes it essential that the estimator should enter against each estimate the date on which it is made, so that, by the aid of his " material " charts, he may be able to make the necessary corrections when the final order comes along. For instance, there may be one or two pounds of an increase per ton of steel between his first estimate and the time when the contract is fixed. On a ship, say, in which there may be several thousand tons of steel this makes a considerable difference in price.

Tendency of Market Prices.—It is usual, unless the firm's accountant or buyer is convinced of an impending fall in the market, to fix the sub-contracts as early as possible, both for reasons of cheapness and to secure priority of supply. It may happen that it is impossible to be sure of an accurate estimate, particularly if the work be absolutely fresh, and if no particulars be available for a similar class of contract. This is not an unusual circumstance in bridge-building, say, or in the design of a very large and speedy liner. In this case it is usual to leave the estimate a little " lucky ", but discrimination must be used in this matter, and attention paid to the " tendency " of the market, whether moving up or down.

Register of Weights of Previous Jobs.—A very important item, if correct estimates are to be forthcoming, is that the register of weights of

previous jobs, complete and in detail, should be faithfully kept and tabulated. Part of this tabulation is usually done in the working drawing office, and part of it either in the counting-house or, better still, the separate costing department.

A book of finished weights should be kept, showing the weight of each part or unit which it is practicable to consider separately. For instance, suppose it is a reciprocating engine installation and perhaps boilers, the record of this installation may be set down thus:

Estimated I.H.P.,
Size of cylinders,
Number and size of boilers,

$$\frac{\text{I.H.P.}}{\text{Cubic feet of cylinders' capacity}},$$

as a heading, which could be amplified considerably.

Then would follow headings of the principal parts, such as:

Main engines.
Fittings on main engines.
Auxiliaries in engine-room and in boiler-room.
Fittings apart from main engines.
Shafting, &c.
Boilers.
Fittings in boiler-room.
Water in boilers.
Condensing plant.
Water in condensing plant.
Spare gear.
Outfit.
Refrigerating plant.
Electric plant.

Each of these should be divided into as many sections as is found desirable. As an example again, take the heading "Main Engines"; this would be split up into sub-headings something like the following:—.

Cylinders.
Soleplates.
Piston-rods.
Air-pumps, &c.

This "finished weight" book should be carefully indexed.

Style of Job.—Again, the cost of a job depends a great deal upon the characteristics of the intending purchaser and his firm's practice.

This may be illustrated by considering three firms known to the present writer—all well-known shipowners.

Taking 100 as the index figure for a normal, plain, and straightforward job, it was found that:

Firm " A " demanded a high finish, the use of brass where the normal practice was cast iron, and many refinements and specialities. It was found in this case that almost 50 per cent had to be added to the estimated cost for the normal job.

Firm " B ", on the other hand, insisted not so much on specialities and finish as on weight. Shafts had to be 20 per cent over Board of Trade requirements; in approving drawings, thicknesses were generally increased, resulting usually in a net increase of weight of almost 10 per cent.

Firm " C " got on the whole a very plain job, but the job he finally got was seldom the job he originally ordered. It was usual for this firm to have several ships building in different yards, and changes in the job were constantly being made, and were a source of vexation and annoyance and extra expense. Further, the changes involved extra cost, but it was very difficult indeed to get these extra expenses paid. As the purchaser was a good customer it was not considered politic to insist always on payment for these extras, so that an extra 3 per cent was generally added to the estimated price to cover these anticipated vagaries. This may not seem to have much to do with scientific estimating, but it led to the erection of charts based on pounds per indicated horse-power which looked something like the following:—

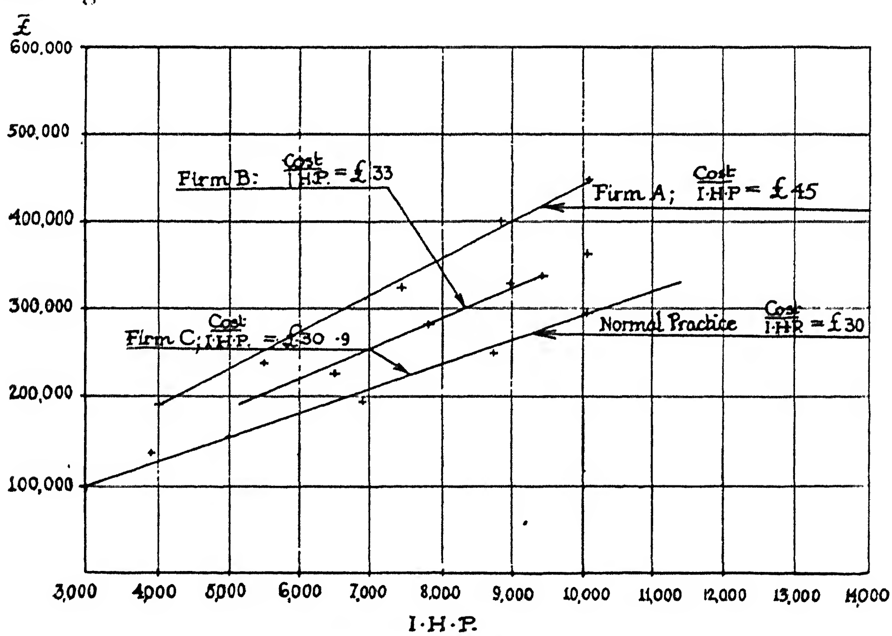


Fig. 1.—Chart of Costs per I.H.P.

This chart shows a method of checking the detailed estimates. It is largely based on estimates received from sub-contractors, i.e. prices based

on overall weights, on indicated horse-power, on volumetric capacity, or on some other recognized unit of measurement.

The estimator should keep an estimate book, and it is good practice to keep a separate book for each job, if it is of any size.

Each item should be shortly but clearly specified. The estimated weight should be put against it, the cost of the raw material, the estimated time of workmanship and the rate of pay, and a column should be written up for the total cost, thus:

Piece.	Material.	Price per Ton.	Finished Weight.	Bloom Weight.	Material Price.	Hours.	Rate.	Work-manship.	Total.
Piston-rod	Bloom D steel, B.S.S.	£12	1 c. 2 q. 21 lb.	2 c. 1 q. 7 lb.	£10 10	10	2*s.*	20*s.*	£11 10

An extra cost would be added, because the total cost of machining is not merely the cost of the actual ingot plus the labour charge—there is an " overhead charge " to be added.

Specialities of other Makers.—In the case of specialities, such as auxiliaries and furnaces, the prices of different makers would be put down, although only that of the successful tenderer would be carried forward to the finished column. This would enable the work to be referred back to expeditiously, in case of a change later on. The customer, for instance, might prefer to pay more to get some particular make of boiler feed-pump.

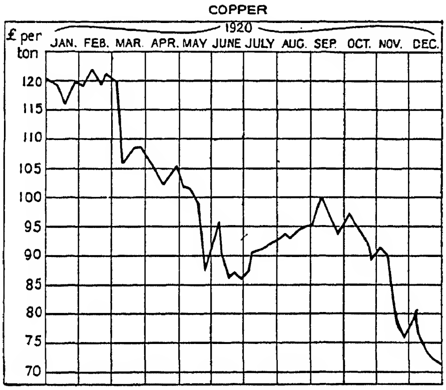
Final Estimate Book.—From this book the finished estimate would be made up, and oncost charges and profit would be added. The finished book containing these two items is confidential, in many places the manager reserving the care of this book to himself.

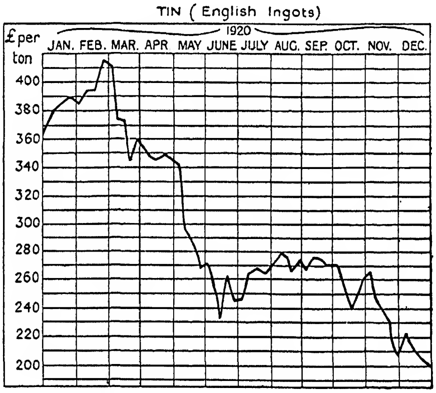
Should a contract be concluded on the basis of this estimate, the details as they are actually finished should be entered up in an abstract book, in which double columns should show the estimated weights, costs, &c., alongside the actual weights and costs. Only thus can the work of the estimating office be properly supervised and checked.

Scales of Wages, Rates of Mechanical Operations, &c.—A scale of wages for different classes of work must be kept, also rates of speeds at which the work can be turned out; say, in machining, the table should give the surface which can be rough turned in a given time, also the rate for finishing cuts, &c., where this process obtains. In other classes of work a piece-work rate per 100 rivets may hold, or the rate may be so much per foot for smithwork on angle-iron, or, in the forge, a price per hundredweight for " light " and a price per hundredweight for " heavy " forgings. This all implies that the estimator shall make himself thoroughly familiar with his own shop practice. It may be necessary for him to get estimates from the foremen, or from rate-fixers, but so far as possible this information should be tabulated inside the estimating office, and as little reliance as possible should be placed on shop estimates, because shop conditions are peculiarly unfavourable to the accurate making of estimates.

Material Charts.—Material charts on squared paper should be kept in the estimating office, and the day-to-day fluctuations marked thereon. Each chart should extend for a quarter- or half-year, but when taken down it should be carefully filed, as, over and above the market fluctuations, it will be found that there are general seasonal fluctuations which it may be advisable to take account of in fresh work.

The material charts shown are completed for a full year. It will be understood that this curve will be gradually traced either by noting daily





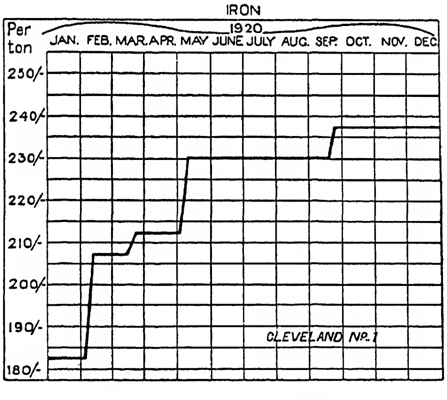


Fig. 2.—Cost Charts of Material

or weekly fluctuations. As a rule, the curve is what is commonly called a step curve, as shown for iron, and is generally marked by a clerk, who watches the markets from day to day and observes the current quotations. Notes of special circumstances may be shown in the margin. It will be known from the data-books how much percentage of these metals enters into total weights, the amount that must be credited to workmanship per ton of metal bought, &c., so that the intelligent use of the charts may bring an estimate out reasonably close to actual results.

On Charges and Profits.—The last two items in the estimator's calculations do not call for any special remark, that is the addition of overhead or running charges and profit. These are generally fixed percentages which are under the direct control of the management. These percentages may be whittled down considerably to gain contracts in a strong competitive market, or even done without, if it should seem advisable, in a period of depressed trade. It may be better to keep the machinery running, even

at some loss, rather than dispense with an organized staff of management and operatives.

Buying.—In large engineering and shipbuilding works it is a fairly common practice to keep the buying of material in the estimating department; but, where this is done, often the general instructions to buy particular classes of goods are issued by a financial manager, whose special province it is to look after the whole commercial side of the firm's activities, leaving the technical side to the technical manager. He keeps his eye on the market, and only sends up such a general instruction to the buyer as: "Buy all copper tubes required for next six months".

The buyer's abstract book should show him, at any time, what material is to be ordered, when it will be required by the shops, when ordered, when to be delivered, terms, &c., and it should always be kept thoroughly up-to-date and properly indexed day by day.

Filing System.—Needless to say, a good system of filing for correspondence, returned estimates, and prints should be adopted. This will be discussed more fully under the heading of correspondence.

The date of sending out for estimates should be carefully noted, also replies tabulated. The date of fixing sub-contracts must be entered as well as the terms. Moreover, a duplicate copy of all prints sent out should be kept, and a fresh copy of the working drawing, initialled by the chief draughtsman, should be sent with formal acceptance.

It may sound very much like an advocacy of the use of red tape, but a very rigid and formal procedure should always be adopted in receiving and dispatching prints. Everything should go through the head of the department concerned, and it is a good plan to keep little order-books for anything required and have the prints initialled. The form of the book, which should be carbon duplicated, might be:

Job No.	Copies Required.	Purpose.	Drawing No.	Title.
581	6	Prices	581/1068	Main boiler furnaces
(Signed) E. Forster, estimator.				
(Countersigned) E. Harper, chief draughtsman.				

This slip would be handed in to the chief of the detail department, who would give it to the proper section leader, who would say whether it was up-to-date. When this was verified, the slip would be given to the photographer, who would take the requisite prints and give them back to the chief draughtsman for initialling before being sent into the purchasing office.

Commercial Information and Contract Law.—The buyer should make himself familiar with the requirements of the departments and their

peculiarities, and should see that a copy of his purchases and contracts are given to the estimator and the ordering clerk. It may even be advisable to send those also to the drawing office, and the department to which the goods are to be consigned, for checking purposes. It is desirable that he should make himself familiar with terms commonly used in shipment and carriage of goods; also with the Law relating to Contract and Sale of Goods. The importance of the 1893 Law cannot be overlooked, and a copy can always be obtained from H.M. Stationery Office.

At all times the estimating and buying departments should be self-contained, with their own clerks and typists, as most of the work is of an essentially confidential nature.

Specifications.—The work of this office will generally cover the preparation of detailed specifications for the owners as to what is being contracted for and supplied. In specifications to sub-contractors the most detailed and clearest specification possible should be aimed at, as it is unsafe to leave out any detail which can be mentioned at all.

In calling for estimates from sub-contractors, it is usual not only to specify the requirements very fully, but in every case to clearly state the time, method, and date of delivery required, also the standard conditions of the firm regarding invoicing, receipt, and payment, and their practice regarding delays due to accidents, such as fire, industrial disputes, &c. These clauses, of course, will naturally be added to the main contract in order to cover the firm with regard to the purchaser. The departments to which deliveries are to be made must be clearly stated, and a copy of order, with price deleted, sent to department.

It is a good plan to insist that, on every invoice and receipt-note sent in with the delivery of material, each item shall be stated, and its actual weight. These weights should be at once transferred in the invoice department to a book specially kept for this purpose, and to books or specially prepared sheets in the different departments, which books or sheets will be sent in regularly to the estimating office or detail office, whichever has charge of the data-book, so that the data-book may be gradually filled up as the job proceeds. If such entering-up is left to the end of the job, much hurry, confusion, and delay may ensue, particularly if the contract be a lengthy one.

Inquiries for estimates should be sent out on standard inquiry forms, say on white paper. When it is decided to accept a particular tender, the acceptance should be again fully detailed and kept on different-coloured sheets, say yellow tissues. These acceptances should be kept separately and filed by themselves for each particular job.

Apart from clerks and typists, the estimating office should be staffed with men who have had good general drawing-office experience, able to understand drawings quickly. All prints sent out for prices should be returned with same, and a note put on the inquiry form to this effect. This procedure is adopted for two reasons: firstly, so that the firm's drawings may not get into the hands of people for whom they are not intended; and secondly, so that, when the contract is fixed and being executed, there shall

be no possibility of work being finished to drawings which may have been intended for prices only, and which it may be desirable to amend as working drawings. No sub-contract should be begun until working drawings are received, and a note to this effect put on the acceptance.

A good estimator must watch carefully and try to arrange to do with the minimum extras, or, where the use of these cannot be avoided, he must allow for same. The difficulty may be exemplified in boiler plates, for instance, which are not simply so much per ton. There is a basic price per ton, say £20. An extra of 2*s.* 6*d.* per ton per 3 in. over 8 ft. broad may be payable, another extra per 5 cwt. on any plate over 4 tons weight, another for certain surveys, one for different thicknesses of plates, and one for tensile strengths, &c. It will be clear from this how important it is to keep in close touch with the design office; for instance, in a large boiler installation, the shells may be specified in one or two strakes, and the difference in prices so caused may be hundreds or even thousands of pounds. Tables of these extras can be got from steel-makers, and up-to-date lists should be kept in the office. A good designer, by skill and knowledge of these extras, may save almost incredible sums to the firm.

Concurrently with the preparation of the estimate should go the drafting of the specification and necessary schedules. This will be submitted with tender drawings to the purchasers, and the schedules will be completed when the contract is entered into, and the whole document will become the guide and general working instruction for the detail office. These specifications are usually printed, and a copy is given to each of the main departments. Copies are carefully executed by the contracting parties with full legal formality. The preparation of specifications is a very responsible job. Many firms have standard specifications, which are used as a basis for the preparation of those finally approved.

Standard Specifications.—During the progress of the late War, an increasing need was felt for the standardization, not only of parts within a firm, but for standardization in relationship to materials, tests, &c. As an instance, it may be stated that the manufucturers of steel plates for boilers and ships sent out lists of standard plates they were prepared to roll, and which, tested at the works by the surveyors of the classification societies, could be had as if from stock, and with the minimum delay. The previous multiplicity of requirements and tests made the work of both designer and detailer very onerous, and not infrequently led to very costly construction.

These differences have been realized by practical draughtsmen for years, but it was the urgency of the War that forced on reform. Recently the Board of Trade, Lloyds, and British Corporation, have combined to make their rules for boiler construction identical, a vast reform when it is remembered that previously every rule was different, and most work for first-class jobs was made under two surveys at least, scantlings to suit the Board of Trade often meaning an increase of weight of about 5 per cent with steel at £20 per ton.

Another side on which much progress has been made is in the preparation by the British Engineering Standards Association (incorporated in 1918) of standard specifications.

The Association has issued, up to the time of writing, 136 Standard Specifications and five interim reports on Ball Journals, Screw Threads, Tyres, &c. All classes of work are covered, and a catalogue can be received by sending a postcard to the Association at 28 Victoria Street, London, S.W. 1. The Specifications themselves cost 1*s*. Specifications are in course of preparation for aircraft materials and components, and a number have already been issued.

The Costing Department.—This department comes more properly under the purview of the clerical staff, but it very closely affects the efficiency and accuracy of the drawing-office work, and particularly affects all future estimates. It is fairly common to find it in charge of a man who has had a good technical training in the drawing office.

How the department is actually organized depends, to a very considerable extent, on the methods of accountancy and stock-keeping adopted in the firm.

In the first place, by keeping a proper set of books, it should be possible at any moment to get the actual cost of all the items delivered against a job. Any material taken from stock should be shown on these books, as, if this be not done, a particular contract might appear to work out cheaper than it really is. Moreover, it is necessary to show what has been taken out of stock, if the amount of stock carried is to be maintained at a level which will enable emergencies to be met easily.

So far as the cost of labour is concerned, separate columns must be kept for the different classes of work involved, also a statement must be made of whether time, piece-work, or premium bonus is the method of payment.

If a premium bonus system prevails in the shops, the rate-fixing department is usually attached to the costing department, and this department may attain to very considerable dimensions with an extremely elaborate system of books.

It would take us too far afield to discuss all the items involved, and indeed it is unnecessary, as the system does not prevail to any large extent in this country, and at present there is no indication of any considerable extension.

The costing department has been mentioned here only because, when a costing system is introduced into any firm, its main outlines are generally worked out in the drawing office, although the details are left to the clerical staff, and because the opportunity seems favourable to emphasize the necessity and desirability of having this department put on a well-organized and scientific basis, with a view to the facilitation of drawing-office and estimating work. The costing system and costing department in most firms are of the most rudimentary description. Temporary expedients and makeshifts have been adopted as the business grew, even where it would have paid over and over again to call in the assistance of a good accountant to make a thorough overhaul and examination of what would require to be

done to put the system on a sound basis. One well-known firm of engineers, of no great eminence fifteen or twenty years ago, created at the time quite a large costing and estimating department, thoroughly examined all the processes of production, tested the capacity and efficiency of machines, and installed new ones where necessary, so that now these departments work like clockwork, and costs, the firm claims, can be known almost to a penny, with the result that even in very bad periods the firm is practically never idle. It has reduced costs to a minimum, and is able to meet successfully the competitive market prices.

CHAPTER II

The Design Office

Closely related to the estimating office is the design office, or, as some large firms prefer to call it, the scientific department. This is a department that only exists as a separate entity in large progressive, up-to-date establishments whose line of business is largely influenced by fresh theory and inventions and is dependent on experimental research. It comes to mature growth where large prime movers are manufactured, or very variable structures such as ships are built. The same need does not arise in structural steelwork, for instance, though many large structural steel firms do maintain such an office. In such cases they are used largely as estimating offices, and it is probably in this direction, rather than in that of research, that their main importance lies.

Technical Questions dealt with.—The design office is usually much smaller than the detail office, and has its own departmental head. It is the function of this office to prepare the original drafts and sketches for new work; to estimate the quantities of material required; to ascertain how far specified requirements can be met. When the main lines of design have been sketched out, the quantities are estimated, and technical questions, such as stability, if the job is the building of a ship, are looked into.

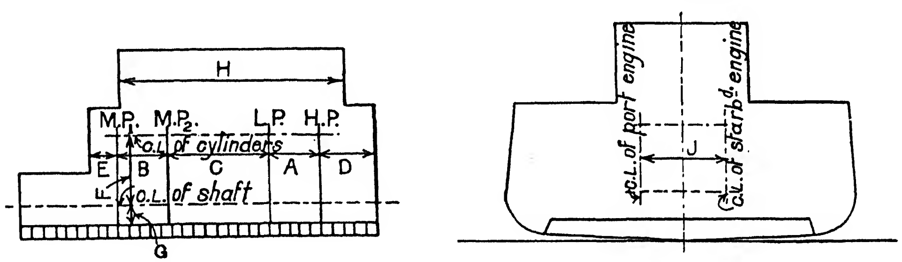
This office, working in close conjunction with the estimating office, will prepare the tender drawings and sketches, and will generally feed the estimating office with fairly detailed technical information. If the contract be placed, the design office will lay down the main outlines of the job, and will generally fix the principal dimensions and scantlings, calculate stresses on parts, and tabulate them in an easily accessible form.

Stress-book.—The stress-book is a highly desirable and valuable record. It should be kept as part of the office work and completely up-to-date by the checker or section leader. If this book be not kept regularly and carefully, the very valuable comparative data kept by the individual draughtsman may be utterly lost to the firm, if such an individual should cease to be employed with them.

Breaking up the Job.—The job can mostly be broken up into a number of well-defined and easily recognizable units, each of which can have a separate section in the data record. These units will be further subdivided, and under each subdivision will be indicated the job identification number and the important dimensions. The material to be used should be entered, the thickness, the working pressure for which the part is designed, the test pressure, the stress per square inch at working load, &c. It is a good plan to mark in the data-book, at the head of each section, the characteristic formulæ applied, and also the safe working load.

Data-books.—It is usual to keep a list of significant dimensions and arrangements, because frequently the thing wanted most rapidly from the design office is the arrangement of an installation, and the accommodation which will be necessary to house it. At the head of such a section should be a list of normal clearances. A specimen page of such a section is given herewith for a marine engine and boiler installation, which will fully explain itself.

NORMAL CLEARANCE. ENGINE ROOM



A = distance between H.P. and L.P. centres.
B = distance between M.P.$_1$ and M.P.$_2$ centres.
C = distance between M.P.$_2$ and L.P. centres.
D = distance to outside of H.P. casing + 3 ft.
E = distance to outside of M.P.$_1$ casing + 1 ft. 9 in.
F = distance from C.L. of cylinders to C.L. of shaft.
G = distance from C.L. of shaft to tank top + $2\frac{1}{2}$ in.
H = A + distance to H.P. casing + distance to L.P. joint + 1 ft. 9 in.
J = 2 distance from C.L. to column foot + 2 ft.

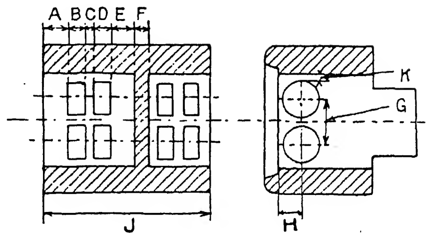
Job No.	I.H.P.	Type.	Size of Cylrs.	Stroke.	W.P.	A.	B.	C.	D.	E.	F.	G.	H.	J.

Fig. 3.—Specimen Page of Data-book (1)

N.B.—Sketch, table, and column all form page of Data-book in each case.

BOILER ROOM

A = 10 ft. 6 in.
B = length of boiler.
C = 2 ft.
D = length of boiler.
E = 10 ft. 6 in.
F = length of cross bunker.
G = mean diameter + 1 ft. 9 in.
H = mean radius + 2 ft.
J = overall length of boiler room.
K = 2 ft. 6 in.



Job No.	Cub. Cap.	T.P.	Type.	Diameter.	Length.	W.P.	A.	B.	C.	D.	E.	F.	G.	H.	J.	K.	L.

Fig. 4.—Specimen Page of Data-book (2)

Special circumstances will always call for special arrangements, but a few normal figures, worked to approximately in every case, very considerably lightens the designer's task, and avoids, as far as possible, chances of large and serious errors. With a system of book-keeping highly elaborated, such as this, the main features of an arrangement design could be sketched on the back of an envelope, and the shipbuilder enabled to make his arrangements accordingly. Even where such a complete record is kept, it is still advisable to go very closely into new designs and check results. Nothing should be left to chance. The designer should know almost instinctively what clearances to test and what scantlings are suitable.

Leading Particulars of Job.—An important work of the design office is the preparation of a fully detailed sectional drawing, showing the important dimensions and scantlings necessary to obtain the certificates of some of the classification societies, which are frequently necessary before the installation can be insured. Typical examples of these are the midship section of a ship, main steam-pipe installations, and marine boiler design. In the two latter cases, however, the working out of these arrangements and scantlings is left to the detail office, the demarcation of what shall be done in each office being a matter of internal arrangement. The classification societies generally considered are the Board of Trade, Lloyd's Registry, the British Corporation, and the Bureau Veritas. In structural work on land, the span of bays for overhead cranes, the distance between columns, the scantlings of columns, crane rails, the size of foundations, the thickness of

retaining walls, and block plans have to be prepared for the local Building Authority. These rules are generally very rigid, and must be closely adhered to. If the contractor fail to comply with them, he is liable to be asked to pull down much of what he has erected and to build afresh. It is therefore important to get the plans approved by the competent authority as early as possible.

Tests.—Another important aspect of the work of the design office is to attend at all tests, and to collect and collate the results of them for future guidance. It is very essential to note very carefully the conditions under which any test is carried out. These conditions should be all carefully put down on the standardized data-sheet, in which the results themselves are shown. The usual method of keeping these results is to have white prints made from a tracing, which show all the various items to be noted. The figures and remarks are marked on these sheets in pencil, and the whole sent into the tracing office and traced. Photographs, either in white or blue, can then be filed for reference. In addition, it is usual to enter the more significant items in a book, as, if dependence is placed absolutely on loose sketches, there is always the possibility of some of them being misplaced or lost. It should be the duty of someone in the office to see that all data-books and sheets are carefully put away at night in the fire-proof safe generally provided for this purpose.

It is usual to plot test results in a graphical form, and to find how much any particular job may vary from normal practice, and if necessary to bring that normal practice up to date. It may be found, for instance, that for some special reason higher working-stresses than usual have been used. If this special practice be repeated on several occasions, and the results are found to be satisfactory, it may be possible to bring the normal practice into line with this special practice, and to alter the basic formulæ accordingly.

Functions of Design Office.—The main detailed drawings and calculations should be submitted to the design office, in order to ensure that the general principles of the design have been carried out.

It will be seen that the design office has a double function in the preparation of designs. In the first place, it has to prepare designs for estimating purposes. The design for this phase must be accurate, but generally need not be given in so much detail as when prepared for the detail office. Indeed, when prepared for the latter, it may be found highly desirable to considerably modify it so as to suit existing patterns, standard gauges, templets, and conditions, which could not have been foreseen when the original draft designs were prepared. The " estimate design " itself may meet with considerable alteration at the hands of the purchaser.

Necessity for Full Information.—It is essential in the design office that the fullest possible information should be put before the draughtsmen, both in the shape of correspondence, similar designs from the firm's own practice and from elsewhere, and the latest scientific and technical information, either in technical publications or the proceedings of learned societies.

Staff and Discipline.—From what has been said regarding the arrange-

ment of the estimating and design offices, it will be observed that much latitude must be given to the highly skilled men employed in them, in regard to freedom of movement, opportunity for observation in shop or on site, and time taken to particular portions of work. This does not mean that discipline need be more lax in these offices; only that it must be of a different kind. It is very probable that the administrative head, whether he be a chief over the whole of the offices or a manager, will spend a considerable proportion of his time in these offices. It pays to staff, and even slightly overstaff, these departments and give them the maximum facilities for carrying on their duties. Heating and lighting are by no means negligible factors, as also satisfactory arrangement of the offices, lavatory accommodation, recording and special instruments, &c. These remarks apply also, in degree, to the detail offices, which it is now proposed to describe. Much of what will be described in the next section applies to these offices, and has simply been omitted so that what is common to them may be treated all at one time.

CHAPTER III

The Detail Office

Organization.—Whether or not the firm be large enough to support separate estimating and design offices, it is certain that the detail office must always exist. In size, it is generally reckoned as the main office, and it is always responsible for the issue of directions to the various shops in the shape of drawings, order-sheets, standards, &c.

The detail office itself is generally split up, in certain classes of work, into two or three more or less well-defined departments. In an electrical establishment, it may possibly be that one portion will deal with the mechanical design of the motors, dynamos, commutators, transformers, &c., whilst another portion will deal with the general installation, placing of switchboards, wiring, &c. In a ship office, we may have a section devoted to the steelwork, another to piping arrangements, and yet a third dealing with accommodation, including shipwright work, upholstery, &c. In a land or marine engineering establishment, the sections will probably be a turbine department, reciprocating-engine department, pipe and machinery arrangement department, and a boiler department. The usual procedure is to have a chief over the whole office, with an internal office with clear windows looking out on to the main office. Under him, and working near him, will be the assistant chief, who will generally look after the discipline of the office, give out work to the section leaders, and correlate their work and generally approve of the finished drawing, discussing points of peculiar importance or difficulty with the chief. All the correspondence will come through him to the section leaders. It will perhaps help to make our meaning clearer

if we describe in some detail the working of a large marine engineering establishment. We shall describe the routine of the work, including the preparation of drawings, the circulation of correspondence, the methods of ordering material, the issue of drawings to the shop, &c. This section will be treated in much fuller detail than the previous sections, as, by doing so, we shall be describing at the same time much of the routine work of the estimating and design offices. The routine of the office having been fixed, it must be strictly adhered to, and only departed from for very special reasons and with the full knowledge and concurrence of the responsible head. This is absolutely necessary if overlapping, omissions, and friction are to be avoided.

The Chief Draughtsman.—This official has the ultimate and sole responsibility for office discipline, and both the qualitative and quantitative production of the work. He must see, as far as he can, that the proper time-table is worked to, and should constantly check the progress made in the various sections. He is responsible for the taking on of new men, and for dismissals, and for the taking on of men or youths from the shops. It will be his duty to grant, or at least advise, what changes shall be made in the staff organization at the proper time, and to investigate any grievances which may be brought to his notice. From his room he can usually overlook the whole office, and yet be easily accessible to callers and to men who may require his attention for important decisions. It is usual for him to have various forms or tables showing a time-table, progress rates, &c.

Programme Table.—A characteristic time-table for a marine-engine office will show, against each job number, the name of the purchaser, the size and capacity of the installation, the contract date, the date of launch and delivery date proposed, and it will be for him to take such steps as he thinks necessary to ensure that these dates are made possible, by regulating the drawings and orders sent out through the order office.

Table of Drawings.—A very desirable table to be kept is one giving the drawings and their characteristic numbers, the material orders, which should be issued in connection with it, the date when the drawing was finished, when traced, and when and to whom issued. Typical forms of these are shown on opposite page.

Each table would be filled up by one of the juniors on each job, who would also do a duplicate for his own section leader.

In addition, an abstract would be kept in the chief draughtsman's room to show the parties with whom the sub-contracts were fixed, with their date; also the date of promised delivery, and of actual delivery.

The time-books kept by each draughtsman usually pass through the chief's hands on their way to the time-clerks, so that he can scrutinize them.

Personal Control by Chief Draughtsman.—It is highly desirable and very usual for the chief draughtsman to go round the office as frequently as his other duties will permit, and so to keep himself thoroughly conversant with the work in the office. It is usual for him also to work in close touch with the heads of the shop departments in order to appreciate properly any

TYPICAL SHEET FOR DRAWINGS

Job No.	Title.	Drawing No.	Drawn.	Traced.	Photo-graphed.	Issued.				
						Smithy.	Pattern Shop.	Finishing Shop.	Fitting Shop.	Outside.
581	Cylinder	581/1	29/11/20	3/12/20	4/12/20	—	5/12/20	5/12/20	5/12/20	1/1/21

TYPICAL SHEET FOR ORDER SHEET

Job No.	Dg. No.	Order Sheet.	Title.	Sent to Copy.	Copied.	Issued.						
						Smithy.	Pattern Shop.	Finishing Shop.	Fitting Shop.	Sub-contractors.		Dele.
										Date.	Name.	
581	1	581/1/B	Planishing	1/12/20	2/12/20	—	—	4/12/20	4/12/20	15/12/20	J. Brown	3/3/21

difficulties that may arise in the execution of the work. Most large firms have a daily council of heads of departments, where ideas are interchanged and matters concerning two or more departments can be discussed.

Office Correspondence.—The chief draughtsman will be responsible for the office correspondence. It is usual for him either to consult the section leader or to get him to draft a suitable reply to a letter in which a number of details are considered. He is also responsible for the issue of all drawings and order-sheets. His own order clerk looks after this work. He keeps a registry of drawings and orders issued, and sees them through into their respective shops or to the dispatch clerk. The order clerk usually keeps the chief draughtsman's books and carries any instructions or messages he may have to give. The chief draughtsman in a large office keeps a typist for his own particular correspondence. This typist generally does the filing of correspondence and keeps the indexes up to date.

General Procedure.—The drawing office must keep in touch with the foremen and erection engineers. The normal procedure is for foremen, inspectors, or sub-contractors who wish to elucidate any point or who desire an alteration to suit shop practice or purchaser's usual requirements, to go in the first instance to the chief draughtsman, who will probably send them on to the man in charge of the job. It is very desirable that this procedure be followed out, so that the chief draughtsman may be thoroughly conversant with any change made during the progress of the work in the office. This procedure eliminates as far as possible controversy at the conclusion of the contract, and mistakes which may arise from departments not knowing of changes made which may affect them.

Assistant Chief Draughtsman.—The work of the assistant chief draughtsman is to be reasonably familiar with the correspondence and the general duties of the chief. He is expected to concentrate his attention on the technical aspect of the work, and it is for him to interpret carefully the intentions of the design office. Drawings going out of the office should be scrutinized by him generally to see that the terms of the specification are complied with and that they correspond with the original designs.

Section Leaders.—The section leaders have charge of one or perhaps several jobs, and work with several juniors under them. The section leader, who is generally his own checker, gives out the work to the juniors, and generally superintends the drawings on the boards, and does a considerable amount of the drawing himself. Having given a drawing to a particular man, he guides him generally, and when the drawing is finished it is taken off the board and carefully checked. The process of checking is one of the most difficult and harassing parts of an experienced draughtsman's duties, as he has to watch the specification very carefully, to see that the general dimensions correspond to the design or guidance drawings, and to assure himself that the various detailed sizes correspond to those on other detailed drawings. Every pipe and valve-flange on drawings and on order-sheets must be individually checked. This is no small matter when it is stated that in the machinery pipe arrangement alone of an intermediate liner of

7000 i.h.p. there may be as many as 1000 pipes and possibly 300 valve fittings.

Having checked the drawing, the details and preparation of which will be more fully dealt with in a later paragraph, it is initialled by the section leader and given to the assistant chief. The latter, after inspecting it, will have it sent into the tracing office, whence drawing and tracing are returned to the section leader. It is usual then to check the tracing with the drawing, the draughtsman's initials being put in the corner with those of the checker, when the drawing can be photographed and sent out for circulation.

Size and Style of Drawings; Instruments; Handbooks.—The size and style of drawings should be standardized as much as possible. It must always be recollected that the tracing-papers and cloths, also photo-printing papers, are made in rolls of 30 in. and 40 in. broad, and drawings should be made accordingly.

A very good size of drawing-paper is the ordinary double elephant size, 40 in. × 27 in., although a smaller sheet, the imperial, 30 in. × 22 in. is frequently adopted. The former is not only a very convenient size when on the board, but is a satisfactory size for handling in the shops, and is economical in tracing-cloth and photo-paper. For large arrangement drawings, paper from the web roll is generally used. This may be the well-known sand-grained paper, or it may be some form of mounted hand-made paper. These can generally be procured in long rolls of 30 in., 40 in., 54 in., and 60 in. width, and the amount required cut off. Where a drawing will be on the boards for a long time, instead of attaching it to the board, as is usual, with small brass-headed drawing-pins, the paper is stretched by soaking, and, whilst wet, glued to the edges of the board. When the paper dries, it of course contracts and gives a very tightly-stretched surface to work on, and which will remain stretched without any ruffling up, as long as the job lasts. It is essential to have the edges of the board planed perfectly true, and also to have a very true T-square, also good set-squares, one of 45° and the other a 60° one. Scales may be of paper, but are more generally of wood, and are much more satisfactory when edged with white celluloid. Ivory scales are frequently used, but they are very costly, and after a time the marking gets rubbed off, and they require to be recut. Where English measures are adopted, the usual scales are $\frac{1}{8}$ in., $\frac{1}{4}$ in., $\frac{1}{2}$ in., 1 in., $\frac{3}{8}$ in., $\frac{3}{4}$ in., $1\frac{1}{2}$ in., and 3 in. to the foot. In modern drawing-office practice, the slide rule is constantly used for multiplying, dividing, squaring, cubing, extracting roots, &c. Each different branch of engineering and shipbuilding possesses its own favourite pocket and handbooks with tables, &c., but these tables are frequently standardized on sheets hung round the office.

Beginning the Drawing.—On beginning the drawing, the draughtsman plans in his own mind how he will space it out for easy reading in the shops, which are seldom so well lit as the office. Centre lines are used as datum lines, and all dimensions should be calculated from them and checking done with reference to them. Generally, two views at least are necessary, and half a dozen may be needed, including, perhaps, an outer elevation,

a sectional elevation, an outer end, and a sectional end elevation, and similarly with the plan. Half-sections are very common. It is common practice to draw the plan, looking down on the article, immediately below the side elevation. The end elevations are usually drawn on the left and right hands respectively of the plan and side elevation. The end elevation on the left-hand side is the end view when looking from right to left; and the end elevation on the right-hand side is the end view looking from the left to the right.

The aim of a drawing should be to portray the article drawn simply, exactly, and completely. All the necessary instructions for manufacture should be given on the drawing. Sometimes this information is given in the form of notes, but it is better to give it in tabular form. It is usual to give overall dimensions to assist the shop foreman to understand at once

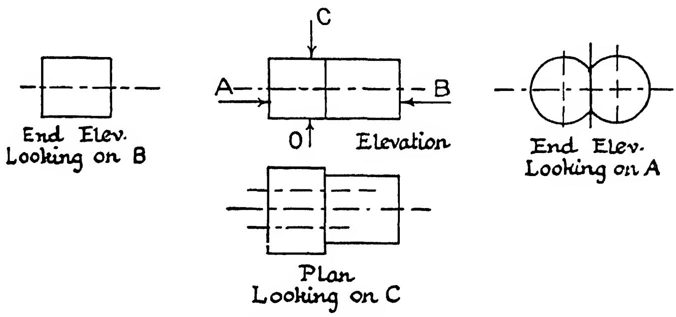
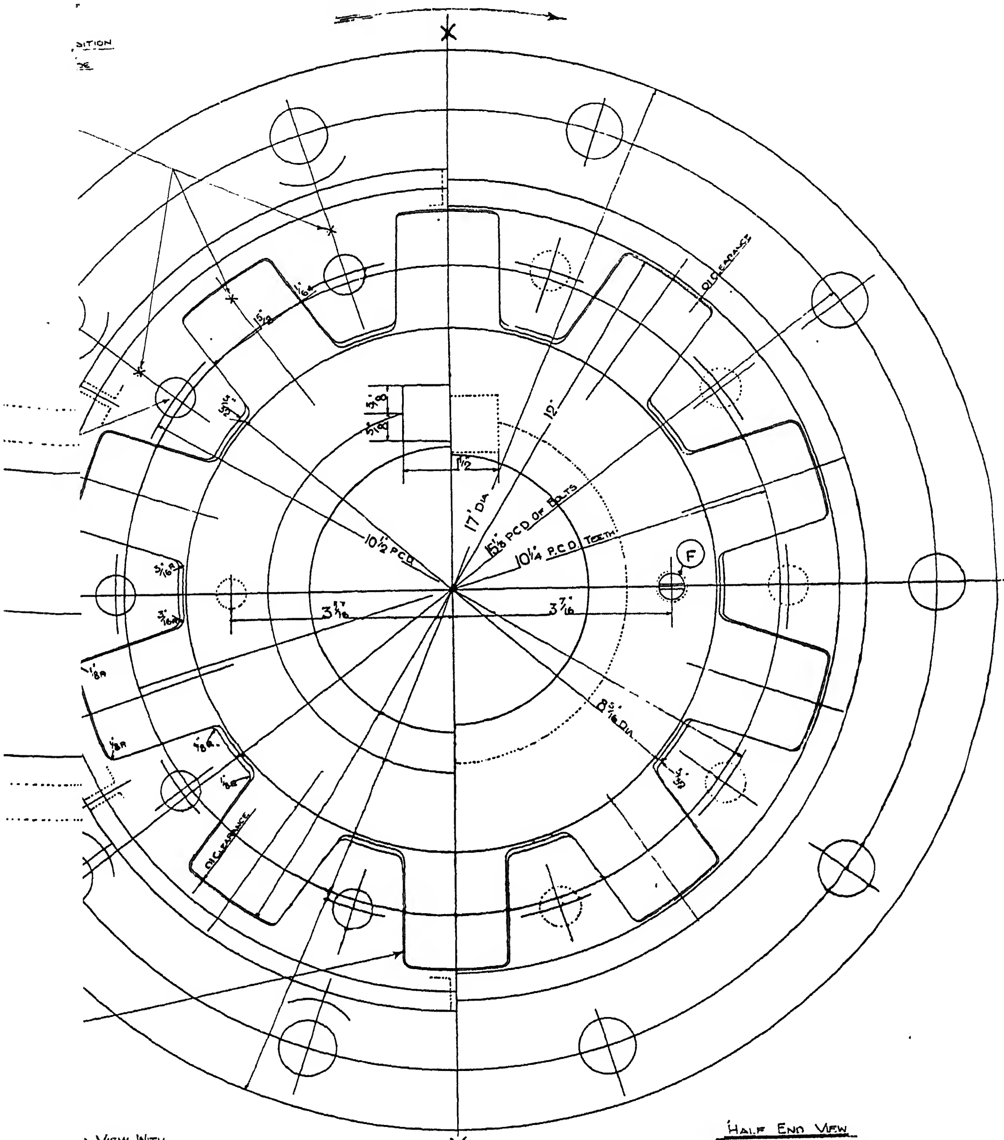


Fig. 5—Disposition of Views on Drawing

the size of piece he will be called upon to handle, and to make his arrangements accordingly.

Dimensions.—Dimensions should be written in large bold figures, and where, as in an arrangement drawing, there are a number of similar parts, each should have a distinguishing mark, such as capital letters of the alphabet. Thus the ground plan for a large works would have the columns marked A, B, C, D, &c., and the different piping systems might be lettered H_1, H_2, H_3 for hydraulic pipes, S_1, S_2, S_3, &c., for steam pipes, &c. These distinguishing marks are of very great assistance in the identification of pieces in the shop, where they will be painted on if wrought iron or steel, and probably cast on if cast iron or gun-metal.

The practice in many offices now is to give all dimensions in a drawing up to 2 ft. in inches, i.e. 23 in., but after 2 ft. in feet and inches, as 2 ft. 7 in. At least one standard, whether it be this or another, ought always to be adhered to. It is usual in large firms to give each part a cost number, so that the actual cost of every detail as it passes through the various shops may be known. This cost number should be shown on the piece, and an arrow should indicate precisely its location. This cost number will also be given in the table at the foot of the drawing, with the location, material, " number off ", &c. In some cases a refinement is made on the cost system, so that



...View With ...her Removed.

Looking Forward

Half End View Looking On Sleeve Joint

...º Engine

Material	Remarks
Forged Steel	
" "	
" "	
Wro't Iron	
Steel Bolts W I Nuts	
Steel	

T.S. ENGINES Nº

H.P. & L.P. FLEXIBLE COUPLINGS

FULL SIZE

Date	Drawn By	Checked By	Issued To:-

Size	
Survey	B.O.T & Lloyds.
Nº of Sheets	One
Sheet Nº	One
Tracing Number	

there is a different number for the material and for the classes of workmanship, but this leads to an enormous notation, which would not seem to give commensurate results. To keep the cost number from being confused with dimensions or "numbers off" it is usually ringed thus: COST Nº 113

In the drawing proper, each part should have printed under it its distinctive name and "number off", also the scale to which it is drawn, if different scales are used in different parts of the same drawing.

All spare parts required should be marked on the working drawings, so that they can be made at the same time as the working parts.

Finally, at the foot of the drawing, its well-known title, such as "piston-rods" or "cylinders", should be given, and the number of the job, drawing number, date of drawing, and scales.

A characteristic title would be

ENGINES No. 783

CYLINDERS

SCALE: 1½ in. = 1 ft.

4 Sheets: Sheet No. 1

Drawing No. 783/1

The table of particulars set out at foot would be something like the following:

Cost No.	Particulars of Part.	No. off.	Material.	Ordered.	Order Sheet.
113	Junk ring studs	64	Steel	21/11/20	p. 63
114	Junk rings	8	Steel	23/11/20	Drg. 783/11

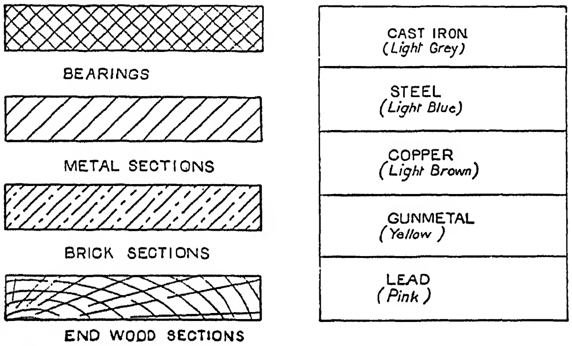
Colour Work.—In some offices a considerable amount of colour work is done, chiefly by juniors, generally to distinguish the classes of material used. Very faint washes only should be used for these, and these should be applied to black-and-white prints rather than to the tracing. There is a fairly well-known convention for materials, such as neutral tint for cast-iron, blue for steel, brown for copper, yellow for gunmetal, and light pink for lead.

Sections are frequently hatched to show up more clearly and to indicate unmistakably that they are sections.

Different offices may have different conventions for colour schemes and for hatchings, but those shown in diagram are those in most general use.

In a coloured drawing, a key diagram of colour scheme should always be given on the drawing itself. This saves waste of time and any possible confusion.

In making many of the arrangement drawings, care should be taken to simplify them to the greatest possible extent. The necessity for this becomes very evident in any piping arrangement, where pipes may cross one another or be hung above others in a great multiplicity of arrangements, and which it is extremely difficult to show clearly. It is usual to make one arrangement drawing showing all the different systems of pipes, for the sake of checking clearances in the drawing office, but such an arrangement is of very little use in the shops, yards, ship, or to men on the site. It is therefore necessary either to colour pipes by systems or, better still, to prepare separate drawings for each system, such as a steam and exhaust arrangement, an oil-pipe arrangement, a lubricating arrangement, a hydraulic arrangement, a sanitary arrangement, bilge and ballast arrangement, &c., as different squads of men will be fitting different systems in all probability. In passing, it may be said the old practice was to take sets and make a great number of such pipes to place. This has largely given place, particularly where pipes of large bore are concerned, to a system of detailing these in the office, and only using closing lengths which are made to place. This considerably adds to the drawing-office work, but saves much time and delay in the shops, particularly as there is a growing tendency to use steel and iron pipes where copper and lead were once very common. The steel and iron pipes can be procured easily in standard lengths, also bends and junction-pieces, at prices very much less than they can be made for on site.



Hatching   Key to Colour Scheme

Fig. 7

Where wrought iron or steel is used it is generally necessary to send out block sketches of the material required, as it may come in " rough forged ". Details are not shown on these sketches, but they give the outline and outside dimensions with the usual extras for working and machining. When drawings or order-sheets are sent out, a copy should on every occasion be filed for drawing-office use. This filing should always be done by one person, say the safe-attendant or drawing-office clerk, and each item should be entered up in a register, giving date and characteristic number. Notes to photographer, authorizing the taking of prints for the shops or for prices, should be initialled by section leaders, and the recall of all drawings from shops for alteration should be done by a note in the office duplication book.

Order-books.—One or more large order-books should be kept for each job, and a duplicate copy of each order sent out should be inserted. The drawing-office order-book is generally quarto size, and made with thin sheets of white paper upon which the orders are pasted. A standard index should be at the front of each book, and the order-sheets for different jobs entered always in the same numbering of pages. The book should, moreover, be split up into convenient sections, and a number of spare sheets left between sections, so that a space may be provided for unusual orders, which, of course, must be specially and appropriately indexed up.

Standard Drawings and Data.—In any large office a considerable number of standard drawings are kept, whereby a very considerable saving of time and labour is effected. It is obvious that it is necessary to have a uniform standard of bolting throughout the work, and, indeed, if the firm can see its way to the adoption of the British Engineering Standards for pipe-flanges, &c., so much the better, and the nearer we shall be to a standard practice and the simplification of design and avoidance of difficulty in repairs. Standards are generally constructed for pipe-flanges of different pressures and material, standard dimensions of bolts, glands, riveting, and other parts of the work that lend themselves to this process. In addition to this, books containing all the dimensions and sketches of the different classes of small fittings used, such as valves, cocks, &c., are kept, and it is only necessary to indicate position of flanges and pieces they join and to add the standard number, to completely specify the piece it is desired to have made. Portions of the work which can be easily standardized in design, although perhaps not in dimensions and scantlings, should be so treated that the addition of the one or two variable dimensions should complete the sketch or order.

Miscellaneous Drawings and Sketches.—In any drawing office there is always a mass of sketches and drawings received from outside, which must be indexed and kept in an orderly fashion. These are either kept in appropriate drawers or in individual pockets or dockets. When drawers or dockets are not available, large square envelopes with tongued flaps are a good temporary substitute. When the drawings are finished with, they can be bundled together and put away in the storage safe, where old records are kept.

These square envelopes should be marked on the outside with the job number and packet distinction, say, A, B, C, D, &c. Each print or tracing kept in them will be A_1, A_2, A_3, A_4, &c., or B_1, B_2, B_3, B_4, &c., as the case may be.

In folding prints it is a good, neat, and satisfactory plan to fold them in Admiralty style, with title, number, and date received, and the origin of the drawing marked clearly on the outer portion. In putting prints back in the dockets, they should always be put back strictly in order so as to minimize loss of time in future searches. It is attention to these small details which tells favourably on the efficiency of an office—saving time, worry, and misunderstanding.

All alterations to prints should be made in red " blue-print " corrector,

and if new prints are sent out in place of any recalled, a red chalk-mark should be added to draw the attention of the shop foreman to the modification.

Time-book.—Each draughtsman keeps a time-book in which he should enter up the time he spends per day on each job. Generally the complete job number will be held sufficient, as few offices do more than make an overall calculation of time spent on any individual contract.

Record of Alterations.—An experienced section leader will keep a list of the alterations made during the course of the job, with a note of the authority from whom he received instructions to make the changes. This practice not only keeps him right in the case of disputes later on, but is necessary, as a set of correct tracings of the job as finished may be required. In this set of finished tracings alterations made outside the office, sometimes without office sanction and at the request of a surveyor or inspector, are expected to be incorporated. This will mean that a few journeys to the ship or site may be necessary and a note of these alterations taken. The working drawings should be altered accordingly in red.

Key Diagram.—In large arrangement work it is usual for the section leader or his most experienced man to make outline key arrangements, and sometimes what may be called a connection diagram. This diagram would show in end vertical column the sources of power, and on top horizontal column the auxiliaries to be driven. In the square common to each put a circle with the bore of the connection. By this means a complete tabular statement of all connections can be given. Such a diagram is the key by which the section leader will check subsidiary drawings and orders.

Such a key diagram is shown herewith, dealing with auxiliary connections for a large marine-engine installation. It is quite possible that the same item shall appear on upper horizontal as well as on left-hand vertical column heading. To show how it is worked, take the item " Steering Engine " in vertical column. We find a circle with the size $2\frac{1}{2}$ in. under the heading " Reduced Steam ". This means that *steam* to steering engine is not taken direct from boiler, but from a reducing valve. Of course the lead to the reducing valve itself will probably be taken direct from the boilers, but this does not affect the key diagram. Similarly, it will be evident that *exhaust steam* from steering engines must be arranged by a suitable arrangement of valves and connecting pieces to go either to main or auxiliary condensers, feed heater, atmosphere, or L. P. turbine. This connection diagram is very often translated with a key sketch actually showing the place of main engines, boilers, and auxiliaries, and lines drawn connecting them. This is not really necessary, as the connection diagram shown should give all that is necessary, but the diagrammatic sketch makes it clear to juniors. It is understood that, in column marked " Makers ", the name of the makers of any auxiliary machinery should be inserted, simply as a convenience to the section leader.

It is usual in large contracts to send such key drawings and diagrams, as well as the principal drawings, to the owners for approval. It is highly desirable to get this approval at an early date, so that material can be ordered early The usual plan is to send two thin prints of each, one of which will

be returned signed or stamped with the owner's approval, and the other retained by the owner for his records. Great discretion is necessary to know which plans it is important to have approved in the first place, as also which parts of the material should be, and which parts can be, ordered first. Orders for material of which only a long delivery can be given should be pushed out immediately; also those portions which, from their position, must be made and fitted first of all.

In the course of his work it is necessary for the draughtsman to make himself thoroughly familiar with the ordinary shop practice, machines, and facilities, such as maximum sizes the machines will take, facilities for handling, crane-lifts and heights, jigs and gauges, patterns in store, dies, and all the implements of manufacture generally.

There should be books in the office containing these items of information, including a list of taps in stock, &c.

Catalogues of Special Parts.—As, in large-scale production, a considerable amount of specialities are bought in finished from outside firms, it is very desirable to have the figured catalogues easily available where such specialities can be seen, and their duties and sizes found. This information facilitates the ordering of the same, and makes for much greater accuracy in the finished drawings. These catalogues should be kept in one place and indexed, and a register of them kept by the office clerk or safe-man, or other person deputed for the task.

In a well-organized office the boards and benches are cleared every evening, loose drawings and tracings are put away in the fireproof safe, order-books put in their correct place, as well as catalogues, &c. Not only are these things saved if a fire does break out, but a great deal of trouble and time is saved, should a particular item be required at an unusual time or when someone may be off work.

Library.—Another very useful adjunct to the office is a library where the larger works, other than handbooks, which deal with engineering matters pertaining to the particular branch of industry in which the firm specializes, are kept. The technical press should also be available in the library for reference. In one or two cases, books are lent out from the library to juniors who are keen to learn anything about the industry they are engaged in. In such cases, the eldest apprentice may be responsible for their issue and safe return. In one office in the writer's experience this plan worked very satisfactorily. This same apprentice frequently has charge of pencils, rubbers, inks, drawing-pins, &c., which are usually supplied to the draughtsmen by the firm. These items constitute a fairly heavy expense in the office, and so far as is commensurate with efficiency should be used as economically as possible.

Use of Tracing-paper.—It is becoming more and more common practice in the larger offices to dispense as much as possible with drawing-paper, using tracing-paper instead. There is much to be said for the practice both on the score of expense and convenience. The economic side of the question need not be laboured, but a considerable amount of the work in an office is of the nature of repetition work, with a few alterations to suit

particular cases, so that the use of tracing-paper may save considerable time. Consider for a moment or two the case of, say, the lubricating pipe arrangement round a large engine or the arrangement of platforms. If it be done on drawing-paper the engines have to be drawn down to scale afresh each time, and it is likely some apparently small details will be overlooked which may seriously affect the arrangement. In a case like this a sheet of tracing-paper can be laid over, say, the carefully made up drawing of the engines, and the leads of lubricating pipes or platforms drawn in on tracing-paper, without a single line of the engines proper. Of course, when finished, it will be advisable to show the main outlines of the engine to convey a quick picture of what is required to the men on the job. Against the use of tracing-paper may be urged the fact that it tears more readily, gets dirty, does not lend itself to erasure, and consequently leads to a good deal of annoyance and irritation, and consequent inefficiency; but if properly and discreetly used, great economy, financial and otherwise, ensues.

Fluctuating Nature of Work.—It is inevitable that there will be periods of extreme pressure. Certain shops will demand work greedily to keep them going, and to get the contract forward at the greatest possible rate. Never may it be hoped that a whole contract can be designed and detailed and modified to the draughtsman's satisfaction before he is called upon to pass drawings and orders into the shop. Skill, judgment, and experience are very necessary to know what things must have precedence. For instance, it is obvious that where large castings form part of the product, time will be needed in the production of the patterns, and a further period must elapse before the foundry can deliver the castings. In the machine shop, moreover, many different operations may have to be performed on one piece alone, and all of them at different times, so that the preparation of such a drawing is generally a first call. But there are obvious risks. The facings have to be fixed definitely when one would gladly do it tentatively, in view of what may crop up at a later stage of the work. But this may not be, and it is seldom indeed that a whole job is finished, and can be looked back upon without a wish that it had been possible to alter many things. It follows that often, in a squad, one or two of the men are trying the most likely small arrangements to ensure that a reasonably suitable arrangement of the major pieces can be made thus early. It is here that experience and judgment are so necessary. But, whilst this is often the case, there are periods of real slackness, when not much current work is on hand. The staff is generally kept up, as it is usually bad policy to deplete a staff which knows the run of the work and the office. During such periods the men are generally turned on to the task of working up the data which may be neglected during times of pressure; of preparing and altering, where found necessary, standard drawings and sketches. This work, whilst it has no visible return at the moment, proves useful in the long run.

Drawings of Standard Parts.—In making standard drawings it is important not only to make the standards for different sizes of the same group of articles show differences which shall be definite and progressive,

such as thickness, &c., but to make the drawings show similar views in similar parts of the drawings, and to make all the drawings of exactly the same size and style. For many classes of work it will be found very good practice to take a sheet of double elephant drawing-paper and divide it in four equal parts by drawing both vertical and horizontal centre lines. In each quarter thus made one standard may be put, complete in all its details. This sheet after being traced will be photographed, so that four standards will be on one sheet. After photographing, each standard may be cut up into a sheet by itself, and perhaps a dozen or twenty of them bound in one book, the covers of which may be formed of stiff drawing-paper, stitched with strong twine.

An example will make the above procedure clear. Most drawing offices have to use steam or water valves in some part of the work. These may be either globe pattern or L pattern, high pressure or low pressure, and made of cast iron or gun-metal. It is obvious here that six standard books will be made up, showing valves, say, from $1\frac{1}{2}$-in. bore to 10-in. bore or thereabout, rising in the smaller sizes by $\frac{1}{4}$ in. each time, and from 3 in. to 7 in. by $\frac{1}{2}$ in., and thereafter by 1 in. The outer cover would be marked, for instance:

CAST-IRON VALVES

220 lb. per square inch

GLOBE PATTERN

STANDARD V2

For standards such as the above, which are in everyday use by a number of men in the office, it is usual to have several sets of each standard, which will be kept in the safe and given out on the requisition of a section leader. On no account should the tracings leave the safe, nor indeed any other tracings, unless for photographic work or for modification, for the loss or misplacement of a tracing is a serious matter entailing considerable work and annoyance in having to be remade, as such may perhaps cause very serious inconvenience at a very busy time, say when a telegraphic request is received for a photograph of some important part which has to be repaired or replaced immediately.

Circulation of Drawings.—It is important to have a fixed routine for the circulation of drawings. Each department may have only a small part to do on any one drawing, but it is general and even advisable to issue the complete finished drawing in each case. It is general practice to do so, because it saves the preparation of several drawings—an important point both as regards time saved and the reduction of error, for the preparation of each fresh sketch or order-form involves risk of error, particularly as such subsidiary sketches would be left for juniors to make. Not only so, but it is a false notion of efficiency to show a craftsman only the little portion of a job he must do. A better job is done because of the knowledge he has of the whole and its general purpose, and he may be in the position to save some part of the process by his practical knowledge when he knows

what transformations it must yet undergo. Incidentally, when this practice is adopted, one tracing instead of half a dozen has to be altered, if an alteration be found necessary.

In designating where prints are to be sent, it is desirable to mark departments rather than the initials of particular foremen, which is a common practice in many places. For instance, in a large engineering work the initial letters of the different shops may be used, as P. S. for pattern shop, F. S. for finishing shop, similarly for erecting shop, smithy, boiler shop, machine shop, dock engineer, works manager, &c. It is usual to send a copy of all drawings to the works manager as well as to retain one for drawing-office use. Moreover, it may be necessary to send one to the purchaser's superintendent and possibly his inspector on the premises. In ordering

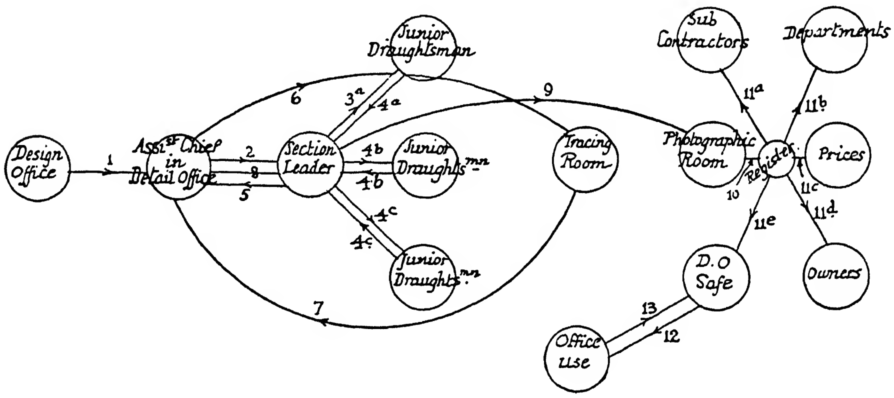


Fig. 9.—Circulation of Drawings

photographs it should be clearly stated whether thin, thick, or mounted paper is desired, and also whether black-and-white paper or the more common ferro-prussiate blue print is required.

Up-to-date practice is to take only the tracings as authoritative text. The drawings after being traced are used no further, nor are they altered if alterations become necessary. They are stowed away systematically, so that, should the tracings be destroyed, the work could be gone over afresh from the drawings. Drawing-office copies are printed off, and are marked for drawing-office use only. These are the drawings in use for reference in the office. The tracings remain in the safe. Alterations are made to the tracings and photographs only.

In order-sheets the designations of the orders may be indicated on the top, either in a printed form or put on fresh on each sheet. The printed form is preferable, with the initials of those departments which are not to receive the drawing crossed out. Thus a typical order heading would be:

Copy sent to: P.S., S.S., F.S., E.S., W.M., D.E., Inspector.

A glance will show where everything has gone to, and its recall be easily arranged if necessary

Many order-sheets are ruled and *printed* in considerable detail, and only want a few sizes filled in by the draughtsman and completed by the tracing or copying office. Indeed, these offices can do a considerable amount of work which will save the draughtsmen very considerable time. For instance, in the case of a large piping-arrangement plan, it is usually necessary to give a list of all the pipes in the job with their distinguishing number, material, thickness, and standard pressure; also a list of fittings, and a list of auxiliaries, such as the following:

LIST OF PIPES

Pipe No.	Title.	Bore.	Material.	Thickness.	W.P.	Order Sheet Page.
1	Main steam from boiler A ..	$5\frac{1}{2}$ in.	W. I.	$\frac{3}{8}$ in.	220	211
2	Main steam from boilers A and B	$6\frac{1}{2}$ in.	W. I.	$\frac{3}{8}$ in.	220	231
&c.						
&c.						

LIST OF FITTINGS

Fitting No.	Title.	Bore.	Material.	Thickness.	W.P.	Order Sheet Page.
R. 13	Main stop valve on boiler C	$5\frac{1}{2}$ in.	Steel	$\frac{7}{8}$ in.	220	167
R. 14	Aux. stop valve on boiler C	4 in.	C. I.	$\frac{7}{8}$ in.	220	194
&c.						
&c.						

LIST OF AUXILIARIES

Mark.	Size of Cylinder.	Size of Pump.	Stroke.	Style.	Maker.	Title.	Cap.
XX	6 in.—6 in.	6 in.	12 in.	Duplex	Blank, Blank & Co.	Sanitary pump	7 tons per hour
&c.							
&c.							

Now these lists will have been made up early in the job on foolscap sheets for the sake of ordering material, and long before the drawings are completed. In such cases it is only necessary to hand these in to the tracing room and have them incorporated in the drawing, indicating only the place and list it is desired to have traced in.

Correspondence.—There is an amazing amount of correspondence passing through the drawing office, much of which does not materially affect the drawing-office work, but which the draughtsmen should see for purposes of information. Unless the correspondence is kept in a very orderly method, hopeless confusion is likely to arise. It is necessary to be able to lay hands on particular letters at a moment's notice, as these letters may contain the records of decisions arrived at in a very early stage of the contract, and which it may be important to know and appreciate at a much later period. Only copies of letters should be retained in the drawing-office files; the originals of all incoming letters should be retained in the typists' room or in a general reference room. Copies of incoming letters should be kept on differently coloured paper from that of copies of outgoing letters. A good practice is to have the former copied on thin white sheets, and the latter on thin yellow sheets. All these sheets should be of the same size, and a stamp in each case put at the top, giving necessary information of the process of circulation or designation.

The white incoming letters have a stamp at the top, such as:

> Copy to: W.M., D.E., D.O., B.S.
> Referred to: D.O.
> Answered by: F.K.
> Ref.—FK/JAD.

and the outgoing letters:

> Copy to: W.M., CH., D.O.
> Ref.—FK/JAD.

The letters sent out the previous evening are generally available for circulation in the morning. Of course the originals, probably signed or initialled by the chief draughtsman, would be checked by him before being sent off, so that there is no need for him to peruse these letters, but he should read letters which are sent out by other departments. Having finished looking over the daily file, he will pass it out to the assistant chief, who will assort them under their respective job numbers and subject-matter, and give them to the appropriate section leaders. The case of incoming letters demands a little closer scrutiny for any new points of importance which will

emerge. The originals of those referred to the drawing office for answering will be retained by the chief draughtsman, whilst at the same time copies of all incoming letters will be circulated similarly to the outgoing ones. The section leader must peruse them carefully, and make a précis of the more

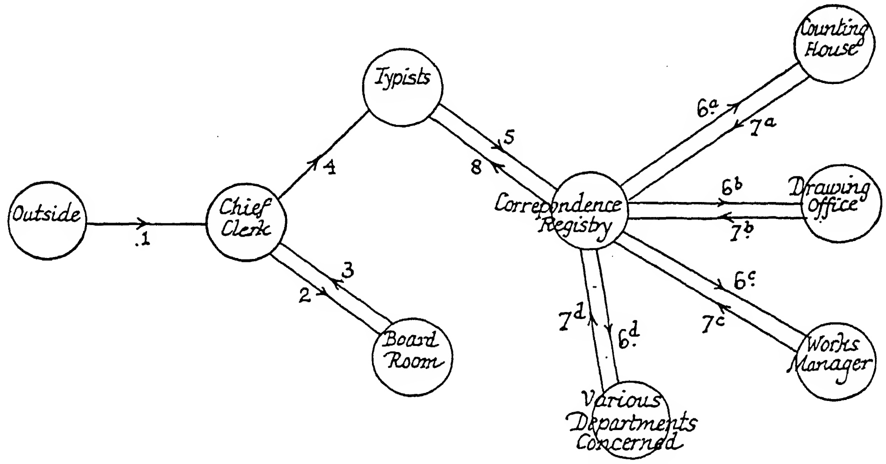


Fig. 10.—Circulation of Letters in Firm

important ones in a book he should keep for that purpose. The book will have a column for the name of the firm from whom the letter came, and its date, also short statement of contents written in précis form. It is desirable to have a further column giving the date on which anything of importance in the letter was given effect to. This means a little labour at the time,

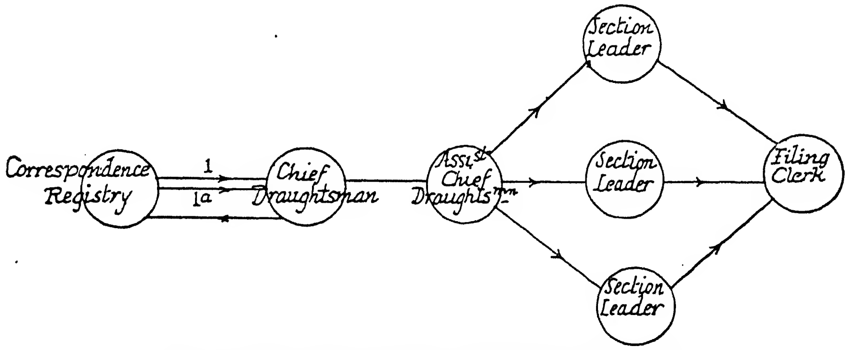


Fig. 11.—Circulation of Correspondence inside Drawing Office

but it is well repaid at a later period. After the section leader or one of his juniors has finished with the correspondence, it will be put in the office filing-basket, from which the clerk or typist will take letters once or twice a day and file them in the proper filing cabinet. There are a great number of filing cabinets on the market, but for drawing-office work a loose folder system is the most suitable, as the letters have to be turned up so frequently.

One drawer of a cabinet will be used for one contract, which should be clearly indicated on the label. A number of stout manila sheets, alphabetically indexed, will be in the drawer, and in each lettered division a folder for each firm under that letter will be inserted. Each folder will contain the correspondence with one firm on one subject.

Perhaps at this point it may be well to indicate diagrammatically how the incoming correspondence in a large firm circulates, and the place the drawing office occupies in the general scheme (fig. 10).

The circulation in the drawing office itself is shown in fig. 11.

Orders for Material.—Orders for materials, either on typewritten sheets or on printed order-sheets, are generally sent out through the order-clerk in the counting-house. There may be very good reason for delaying to issue these orders, but in such delay there is a distinct chance of the order being altogether overlooked. At least, if the sending out of the order-sheet is all the drawing office knows about it, there is no chance of a forgetful order clerk being reminded that the material will be required in a measurable period of time, and if an order-sheet gets lost, serious disputes may arise as to which department was at fault. In many cases now the original order-sheet sent to the order department is not sent out, but is split up, if necessary, for buying purposes, and a fresh order made, say on a differently coloured paper. When this is received by the drawing office, it is a guarantee that the order has been passed through by the order-clerk. The section leader in his notebook for order-sheets will have several columns which will clearly mark its progress and destination, such as:

ORDER SHEETS FOR JOB NO.

Page.	Title.	Prepd. by.	Sent to Copier.	Retd.	Issued.				From Order Office.
					P.S.	S.S.	E.S.	Order Clerk.	

All drawings and order-sheets issued should be stamped with the name of the firm, the department, and date of issue. They should also be initialled by the chief draughtsman or his assistant.

CHAPTER IV

Tracing Office

In the larger offices, women are now employed as tracers. Many of the best technical men are by no means the neatest draughtsmen. Whilst it is important to have drawings made carefully, neatly, and to scale, it is of only secondary importance that the actual drawing should be of a high finish. Neatness of line finish is only an incidental accomplishment to the expert designer. But all the same, it is most desirable that the prints sent down to the shops should be neat and clear. For neatness girl tracers cannot be surpassed, and it is wonderful how even the most complicated and elaborate arrangement, say of general piping for a large battleship or liner, can be made clear by people who do not know the mechanical details or understand what each line signifies.

The tracing office is kept apart from the drawing office, but for obvious reasons should be contiguous to it. It is under the charge of a head tracer, who takes her instructions from the chief draughtsman and apportions the work amongst her own staff.

Linen Tracings.—Most tracings nowadays are made on tough linen, made clear with a highly starched glazed surface. The drawing is pinned down, and a piece of tracing-cloth is stretched over it. It is necessary to tear off a strip along the borders, as at this portion the rolls are generally wrinkled, and if this selvedge were allowed to remain on, it would be very difficult indeed to get the cloth properly stretched. This stretching does prove rather troublesome, as the tracing-cloth is apt to stretch very considerably. It is usual to stretch it tightly over the drawing for an hour or two, or, in the case of a very big plan, overnight, before beginning work on it, otherwise it would be found that if the tracing were right over the drawing in one place it would not be so in another.

Making the Tracing.—The surface worked on is a highly glazed surface. Water takes out the glaze by destroying the starched surface, and makes the cloth opaque and useless for photographic purposes. It is therefore essential to take care that no water gets on to the tracing. Moreover, a crack in the tracing will show clearly on the photograph, so the tracing should never be folded, but should be either kept flat or carefully rolled up.

To prevent the ink running on the surface too freely, ground French chalk is rubbed over it to enable the ink to grip.

The purpose of the tracing is to obtain the sharpest line photograph possible. No half-tones are required. For this reason the tracing-cloth should be as transparent as possible, and the ink as opaque as possible. Many of the opaque papers have a strong yellow tinge, and if an ink without much body in it be used, we get either a faint blue background, where ferro-prussiate paper is used, or indistinct white lines, making a more difficult photo print to read than need be.

Ordinary blue-black or red writing ink is absolutely useless to get a clear line. The main portion of the drawing, certainly, as well as the printing is done in black Indian ink. The ink should be mixed freshly every morning, and ground down in a white-enamelled china palette to a consistency which will at once run freely and at the same time give a perfectly black line. A little gamboge mixed with the ink helps to make it more opaque. For centre lines and dimension lines a less prominent line will do. It used to be common to mix up crimson lake with water to a very thin syrup for this purpose, but it was not generally dense enough, and has largely given place to the use of burnt sienna. Several firms, indeed, use nothing else but black, chain-dotting centre lines to distinguish them from outlines. Where it is desired to show things faintly, such as ladders and platforms about an engine installation, Prussian blue is employed. As a general rule, tracings should be made with firm, slightly heavy lines, if the most satisfactory working drawings are to be obtained. Very thin lines do not come up well in the photographic process. Some of the inks can be washed out easily with water, and it has become fairly common of late to use bottled waterproof inks in the tracing office. These are much more difficult to erase. If alterations are desired in a tracing, it is better to have a small sketch of the alteration sent into the tracing office, and the erasure and alteration made there.

When the tracing is finished it should be checked, size for size, with the original drawing, before being allowed to leave the office. The printing and figuring should be as clear as possible, and, in fact, it is becoming general practice to tolerate straight up-and-down lettering only.

Copying Order-sheets.—The copying of order-sheets is generally done in the tracing room. The old method was to press the sketch and lettering through from the original sheet, by means of carbon papers, on to the half-dozen copies required. Modern appliances have got rid of this laborious and rather barbarous practice. The order-sheet sent in from the drawing office is only drawn in pencil. The tracers go over it with a special ink capable of taking a considerable number of copies. This is put on top of special gelatine sheets and a roller run over it, so that an impression is taken on the gelatine. This gelatine impress is now used as the original to take the required number of copies, generally on thin tissues. Two or more coloured inks can be used in the process, which leaves the order-sheets very clear and satisfactory.

Several odd jobs find their way to the tracing office, although it is not strictly tracers' work. These are the correction of a number of specifications from an original copy, the writing up of the data-book in ink, which has been filled in in the drawing office in pencil. In short, the tracing office does any job arising in the drawing office that calls for neatness.

CHAPTER V

The Photographic Room

Sun Prints.—In the olden days the method of printing was for one of the apprentices to run up to the roof with the tracing and put it in a flat printing-frame, similar to that used by the amateur photographer but of course very much larger, and to leave the sun to do the rest. This method is only tolerable where the number of prints required in a day is small. In large offices, not only is someone required to take off prints all day, but a much more rapid method is necessary. The photographic room has become a well-equipped and indispensable portion of the drawing office. In an office employing about twenty-five men, the writer has known 120 large photographs being taken, dried, and dispatched in one day, including all the necessary indexing, &c. This keeps one man busy the whole day, as quite a number of the prints are black-and-white ones, which take about six times longer to print than the usual blue prints, and require considerably more washing.

Equipment of Photograph Room.—Not only must the photographic room be well equipped with an up-to-date electric printing-frame, but it should have several large baths for washing, a plentiful supply of water, a permanent squeegee, a good drying oven, and also a considerable number of laundry rods for natural drying. A table with a hard wooden top should be provided, a large steel straight-edge, or better still an automatic grip, and a deep-cutting knife. Ventilation is highly important, as the drying oven is generally a gas one. The fumes of the oven are apt to lie about the room, and the process of natural drying is very slow if a good current of air is not available.

Procedure for Obtaining Prints.—When prints are wanted, the section leader wishing them enters up a requisition form, which is printed in a small manifold book. Alternate leaves of this book are printed perhaps on pink paper, and have perforations for detaching them. The copy leaves are unperforated and may be white paper. The ordinary carbon sheet is used to get the duplicate. A sample page is given herewith.

Perforation	Job No. 531. Date 11/11/20. Title: Foundation Plans. Drg. No. 531/87.		
	No. off.	Sent to	Kind of Print.
	1	D.O.	Blue mounted
	2	Inspr.	„ thin
	2	Owner	Black-and-white mounted
	1	F.S.	Blue, thick
	1	E.S.	„ „
	1	W.M.	„ thin

Kinds of Prints.—The blue print is the cheapest photo print and the one most suited to general shop purposes. It costs less than a shilling per yard.

Blue prints for mailing purposes are taken on a very thin paper. For machine shops, where a print will be required a great deal, and where it will probably be pasted up in frames to keep it flat and to prevent it from going amissing, a mounted blue print is preferable. This is a paper blue print mounted on a tough linen backing, and it forms a very firm print indeed, being like a thin cardboard when washed. Sometimes a linen cloth is used. This is durable, very soft, and is suitable for folding, but the parts of the fold are apt to rub off.

Prints which have to be coloured, say for the approval of owners, are generally taken on black-and-white paper, i.e. black lines on a white ground, and if occasion demands it, on black-and-white mounted paper. This paper is much dearer. It costs probably four times as much as the blue paper, and it takes longer to print. The white ground if slightly under-exposed is apt to look dirty, and if slightly over-exposed the lines may, if traced thinly, come out rather faintly.

Printing Machines.—A fairly common type of printing machine is one formed of two semicircular cylindrical pieces of plate-glass, which together form the curved wall of a cylinder which is open at the ends. Two prints are usually put in at the same time, one on one semicircular portion and one on the other portion. An arc lamp is hung from the roof over the centre of the cylinder. The cylinder swivels, so that it may lie horizontally when putting in the tracing, the face of which lies against the glass. Over this is placed the photo paper, and then a felt backing is strapped on to keep it in position. When these adjustments are satisfactorily made, the cylinder is tilted on end so that the electric lamp may travel down its axis. The speed of travel of this lamp is adjusted by a clockwork arrangement. As the lamp falls gradually to the bottom the light is reflected on to the glass and the tracing, which it penetrates. The light affects and fixes in some degree the chemical surface of the paper. The black lines of the ink prevent penetration, and the unfixed chemicals are dissolved away in developing, leaving a white line on a blue ground, or a black line on a white ground, and there are papers with white lines on brown grounds, &c. The defect of this type of frame is that the length as well as the breadth of the print is limited, at least without folding and to some extent damaging the tracing. Not only so, but unless the lamp has been carefully wound clear of the frame, it may be broken in swinging the frame to the horizontal position. The semicircular cylindrical glass, moreover, is very costly to replace, and awkward to handle in such a contingency, and the portion of the print at the bottom is liable to have longer exposure than the top portion. The latter defect betrays itself in a slight unevenness of ground-tone. Of late years a flat plate-glass horizontal frame, which works on an endless roller system, has been introduced. This frame takes prints of any length, say those common in shipyards. The arc lamp travels horizontally at a fairly

quick speed, and on either side of it is the flat plate-glass of the width of the machine. A print can be taken on either side, and each side can be geared to different speeds of feed, so that they may be kept geared one for blue prints and one for black-and-white prints. The lamp travels backwards and forwards like a shuttle, and is operated by an electric switch. The frame is never removed, so there is no danger to the lamp, and if a

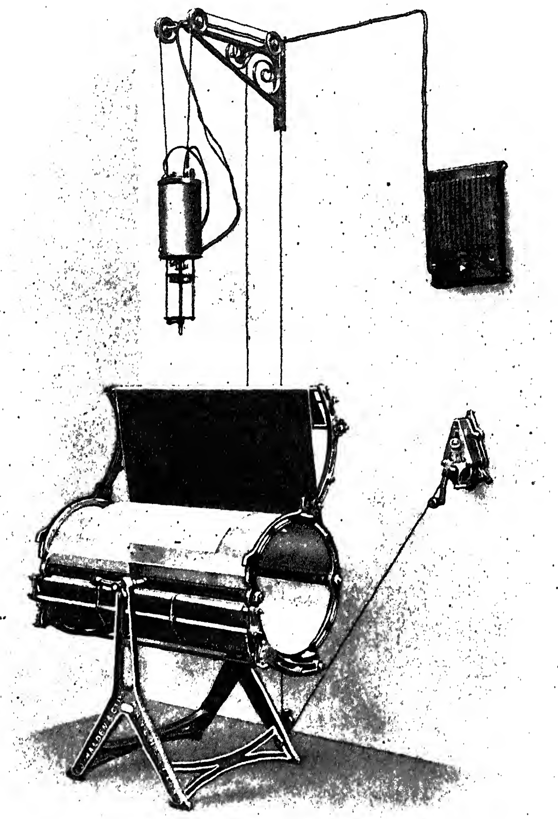


Fig. 12.—Halden's Duplex Radial Electric Photo Copying Frame. Prints being inserted.

sheet of glass does get broken, there are generally a number of spares kept so that it can be replaced very quickly and readily.

Prints of both circular and flat glass types of machines are shown (figs. 12 to 14). The former is technically known as Messrs. Halden's Duplex Radial Electric Photo Copying Frame, and the latter is the same firm's Double Pattern Single-lamp Type Continuous Electric Photo Copying Machine, and both are shown by the courtesy of Messrs. Halden, who very kindly supplied the blocks for these illustrations. In the case of this latter type, the single-lamp type has now almost entirely superseded the original machine, which

had two or even three stationary lamps instead of one moving arc lamp. The current consumed is less, and less expense is entailed in replacing chimneys and carbons; moreover, the glasses can be placed nearer the lamp as a less amount of heat is generated, thus avoiding to some extent the danger to the glass by overheating. Prints can therefore be taken as rapidly with one lamp as with several, and a more even exposure is obtained.

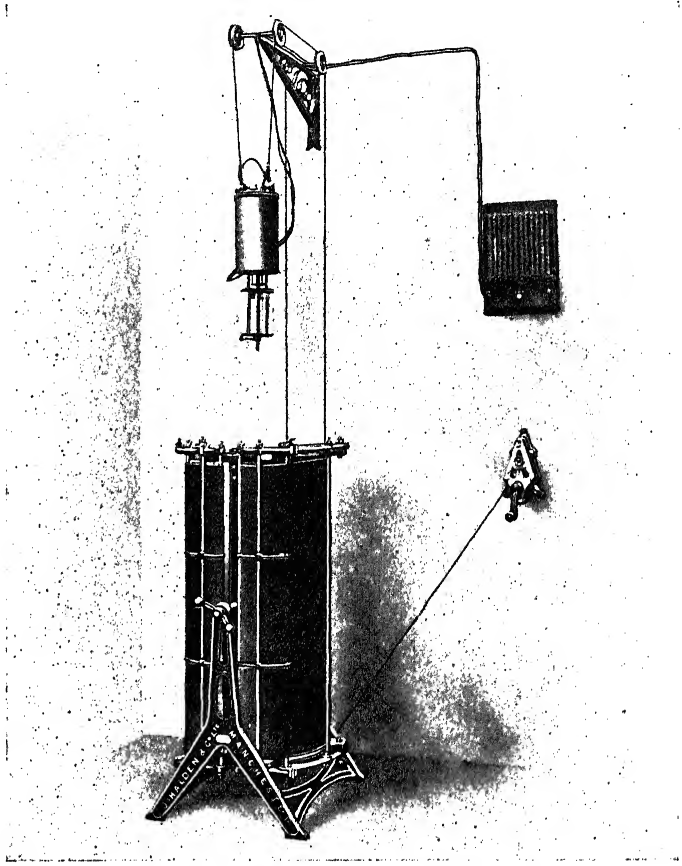


Fig. 13.—Halden's Duplex Radial Electric Photo Copying Frame. In position for photographing.

A recently improved form of machine (fig. 15), also supplied by Messrs. Halden, has been put on the market, called the Rowsley Super-continuous Electric Photo Copying Machine. It is claimed for the machine that it is more economical than previous patterns in the use of electric current and that it enables the operator immediately to increase the output.

The tracing and photographic paper are fed from a table, and are taken close up against the glass by slow-moving rollers. When the end of the tracing comes out, the photographer draws his knife sharply along the photo paper at the top of the table, which is a glass slab, and lets it work its way

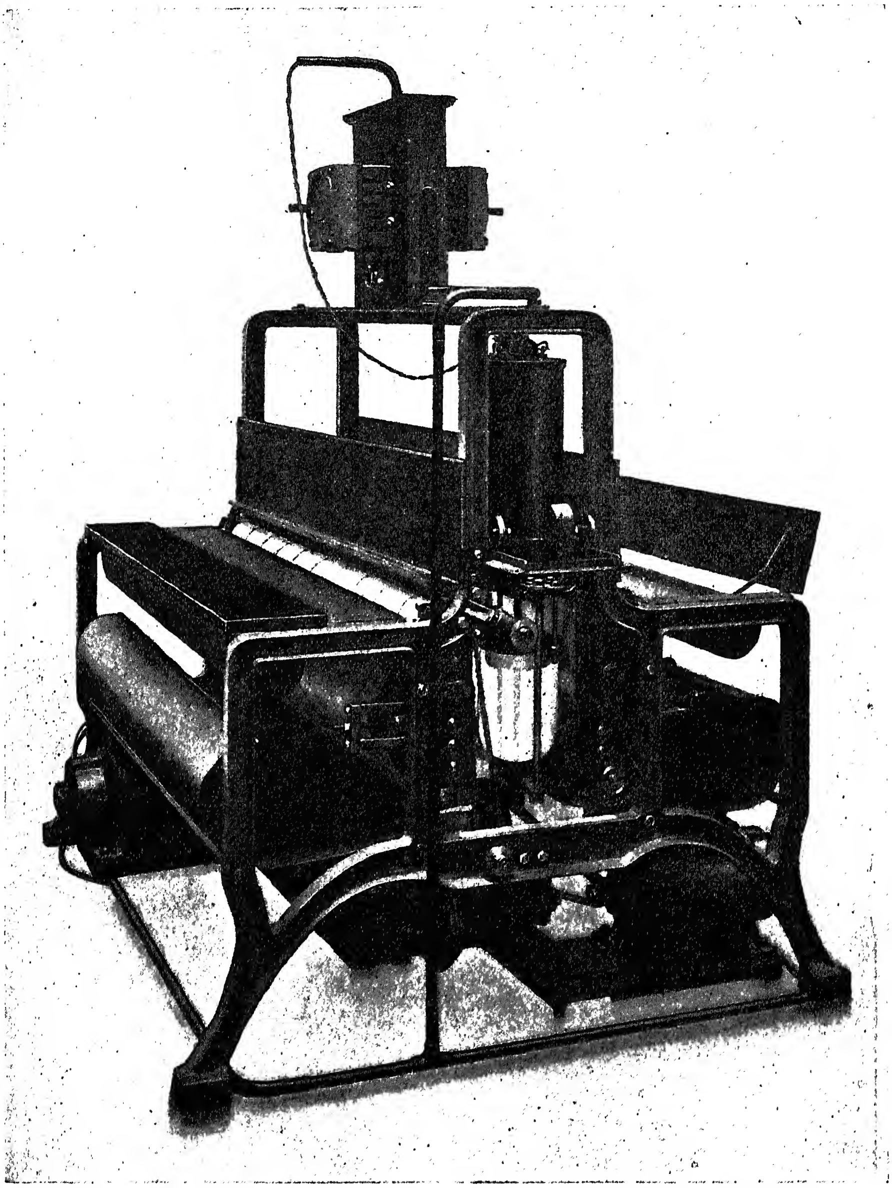


Fig. 14—Halden's Double-pattern Single-lamp Type Continuous Electric Photo Copying Machine

down in a few moments to the receiving trough underneath. A considerable number of photographs may be taken off before the washing process is begun. Often the photographic room is placed high up in the building, a relic of the time when sun printing was the common practice. This is often responsible for an insufficient supply of water. The bath should be kept perfectly clean, as considerable sediment comes off some of the photo papers. Indeed,

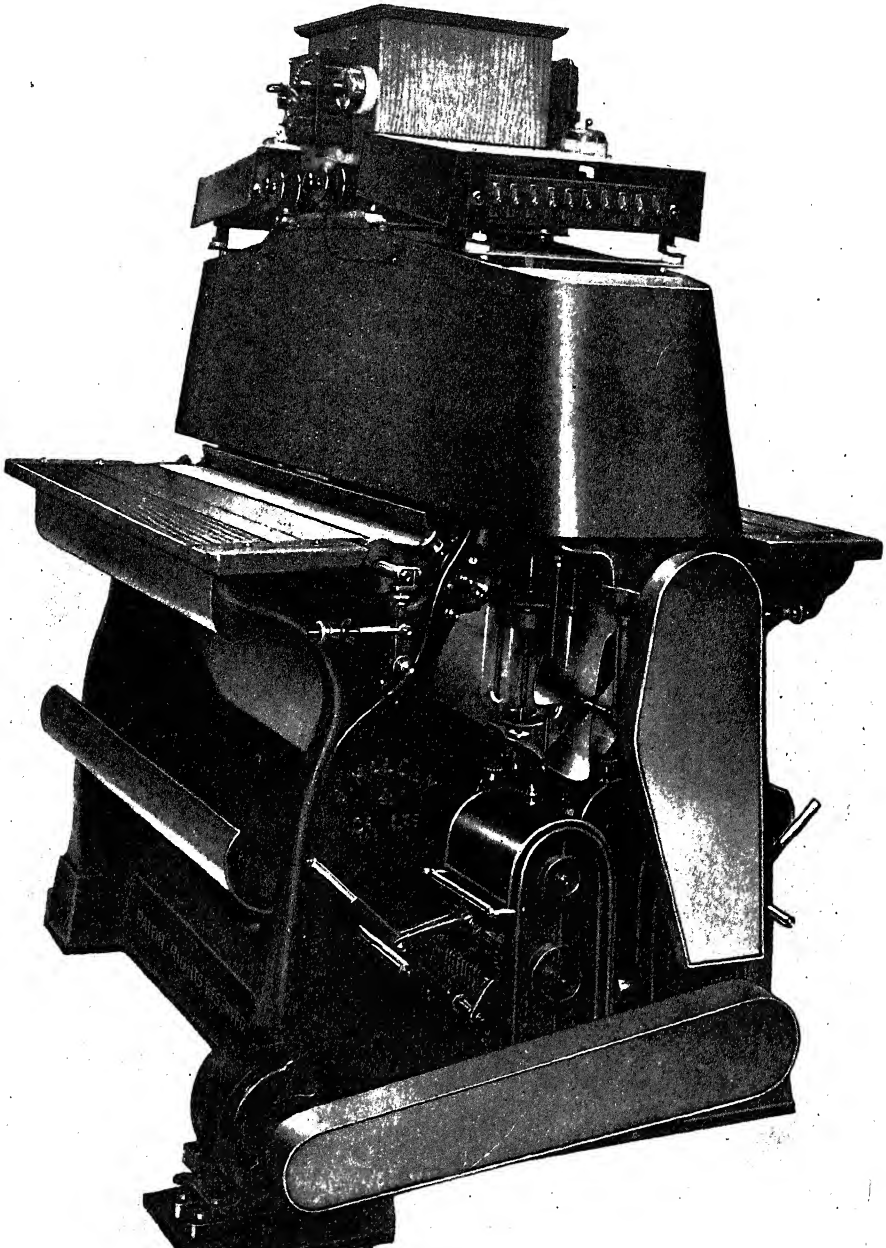


Fig. 15.—Rowsley Super-continuous Electric Photo Copying Machine

the ideal system is to have a continually running supply, so that the bath is kept constantly fresh. The photograph is immersed, and a small hose made to play on it to drive off every particle of surface chemical. Separate baths should be kept for black-and-white prints and the ordinary blue prints, if satisfactory results are to be obtained. When thoroughly washed, the print should be drawn through a squeegee, permanently attached to the side of the bath, to take off as much of the surplus water as is possible. If the groundwork of black-and-white prints comes up slightly muddied, it may be chemically treated to bring it up white, but great care must be exercised in this treatment lest the black lines of the drawing should get obliterated.

It may be of some interest to the operator, or draughtsmen with some knowledge of chemistry or photography, to briefly indicate the chemical reactions with either the ferro-prussiate blue paper with white lines or the ferro-gallic white paper with black lines.

In the former the paper is coated with potassium ferricyanide and ferric compound of iron. When exposed to the influence of actinic light, either from the sun or the electric arc, part of the iron in the sensitive compounds is changed from the ferric to the ferrous condition, which with potassium ferricyanide gives an insoluble blue compound which is precipitated on the paper. Side by side with this reaction a portion of the potassium ferricyanide is reduced to potassium ferrocyanide, which, with the unchanged ferric iron, also deposits a blue compound on the paper. The net result is that a complex mixture of blue compounds is laid down on that portion of the paper, i.e. the background, which has been submitted to the ultra-violet rays. The portions unaffected because of the protection afforded by the ink on the tracing are washed away in the bath, leaving the white lines on a blue ground.

Similarly with ferro-gallic photo paper, i.e. paper which gives black lines on a white ground. In this case the paper is coated originally with a solution of iron salts, the ferric compound being reduced by the action of light to the ferrous state. The paper is now treated with a solution of gallic acid, which changes the ferric iron on the parts shielded from light into a bluish black compound. The exposed portion, where the transformation from the ferric to the ferrous state has taken place, is unaffected.

In water bath, or one bath ferro-gallic paper, the coated material carries its own developer in the form of a powder on the surface. With this paper, on immersion in water, after printing, the ferrous salt, with the gallic acid in contact with it, is washed away, leaving fixed on the paper the black compound of ferric iron and gallic acid.

Drying of Prints.—The prints are caught by spring clips at the edges, and hung up to dry. It is better to let the prints dry naturally, as artificial drying is apt to distort them badly, especially where they dry last.

Register of Prints.—A photo register is kept by the photographer, showing when each print was sent out, and what was its destination.

The Safe

The protection of drawings, tracings, and books, from loss by fire, theft, or careless destruction, is important. The safe is usually a strong-room, a room built of brick and iron, asbestos-lined, and provided with steel-shuttered windows and steel doors. The safe may be of considerable dimensions, and is generally staffed by a man in charge and one or two office-boys. The safe should be well fitted up with drawers, pigeon-holes, serving-table, voice-tube connections to chief's room and other departments, and should be well lit and ventilated.

When a new tracing is made and checked, it should be at once given into the custody of the safe-man, who will enter it up in his book, also the date of receipt. This entry will be transferred to his permanent tracing register, where it will be entered under the proper job and drawing number. The original drawing, which will be passed in at the same time, will be filed away, probably in another part of the building, as it will not usually be required again. In any particular job the drawings may number anything from 20 to 200, and probably in certain cases many more. It will usually be found undesirable to roll up more than ten or twenty tracings together. Drawings 1 to 10 will be in one roll, 11 to 20 in another, and so on. These rolls are best kept in japanned tins to keep them from dust and damp, or, failing that, in canvas covers. They should always be very carefully rolled up and handled, the surface never being cracked nor the corners allowed to be folded back. Every crack in the tracing means a line not intended in the print.

Tracings are only given out for photographic purposes, or when it is intended to alter the tracing; and when a tracing or a print is given out, the date of issue and the draughtsman's name should be jotted down in a day-book kept for that purpose.

When a new tracing is given in, the safe-man should see to it at once that the proper office copies are taken off, as prints are now almost universally recognized as the standard form of drawing-office copy.

The same procedure will be adopted with the prints and sketches received from outside, or copies of sketches sent out, except that, in the latter case, it would be the only available copies which would be given out when required.

All the order-books are kept in the safe, and occasionally the data-books, although these latter are more generally kept in an ordinary small iron safe in the chief draughtsman's room.

Estimate drawings are, of course, entered up in an estimate-book and filed away appropriately.

In the best firms no one but the safe-man, and whatever assistants he has, enters the safe, all transactions taking place over a counter. The drawing required is called in, and it is usually left to one of the office-boys, attached to the safe, to bring it down to the draughtsman who requires it. These

boys generally do any clearing away of benches which may be necessary at night.

A well-kept safe not only ensures the safe custody and well-being of records contained therein, but facilitates the usual routine work of the office in providing what is required with the minimum delay and vexation.

Evolution, not Revolution, desirable in Drawing Office.—Such, in outline, is the usual office organization, which we have discussed less in a systematic theoretical manner than as good common practice in many offices throughout the country. There are many items of organization to which radical alterations may be made with advantage, but we have to consider that, in most cases, even a relatively small alteration to modes in common practice may produce very considerable dislocation for a time. An alteration in the size of order-books, for instance, or the sequence of their pages, causes a certain amount of confusion in an office, because all the old records are done in another fashion. This point can only be appreciated by those who actually have worked in an office at the time of such changes.

The Human Element.—To the ordinary draughtsman each individual job is a job by itself which he must seek to do as satisfactorily as possible. He follows the instructions of a senior, and if he interprets them intelligently he is not likely to go far wrong. To the section leader each job is merely a small thing in a very large contract; he has to look a good deal before and after, and may, out of his long experience and knowledge of what may be expected at a later period, make many decisions and give many instructions to a junior which do not at the time appear very convincing. The contracts in the engineering industry are so large that large sums of money are generally involved in the smallest decisions, and mistakes are likely to be very costly ones. It is therefore necessary to let men think out the tough problems that fall to their lot, and it is a false economy that keeps the section leader's nose to the grindstone when he can perform a much more valuable service in supervisory and advisory work.

The work of the chief draughtsman, whilst it includes that of the section leader, calls especially for personal qualities. He must see to it that no serious friction arises in the office, and that information is freely given. Occasionally serious errors result from feelings of jealousy and bad feeling which prevent one man giving another the fullest information. It depends very much on the character and tact of the chief, whether this spirit or one of good fellowship shall obtain between the members of his staff.

There is a tendency with the larger firms to achieve efficiency by means of stringent discipline. Discipline, of the Prussian type, can be carried too far—better results can often be achieved by giving conscientious men some freedom of action. It has become very frequent of late to introduce time-clocks into the office. No one, of course, denies the value and desirability of punctuality, but it must be remembered clocks measure time, not work done.

Grievances should never be allowed to grow, but should be attended to at a very early stage. Frank and free discussion will frequently remove

the most serious misunderstanding, and it should be realized that serious grievances are often due to, and are kept alive by, a lively sense of some real or supposed injustice. Such grievances are seldom confined to individuals, but quickly spread to large bodies of men. Fortunately with tact they can usually be met and rectified.

One or two other points of a general nature have to be considered, and,

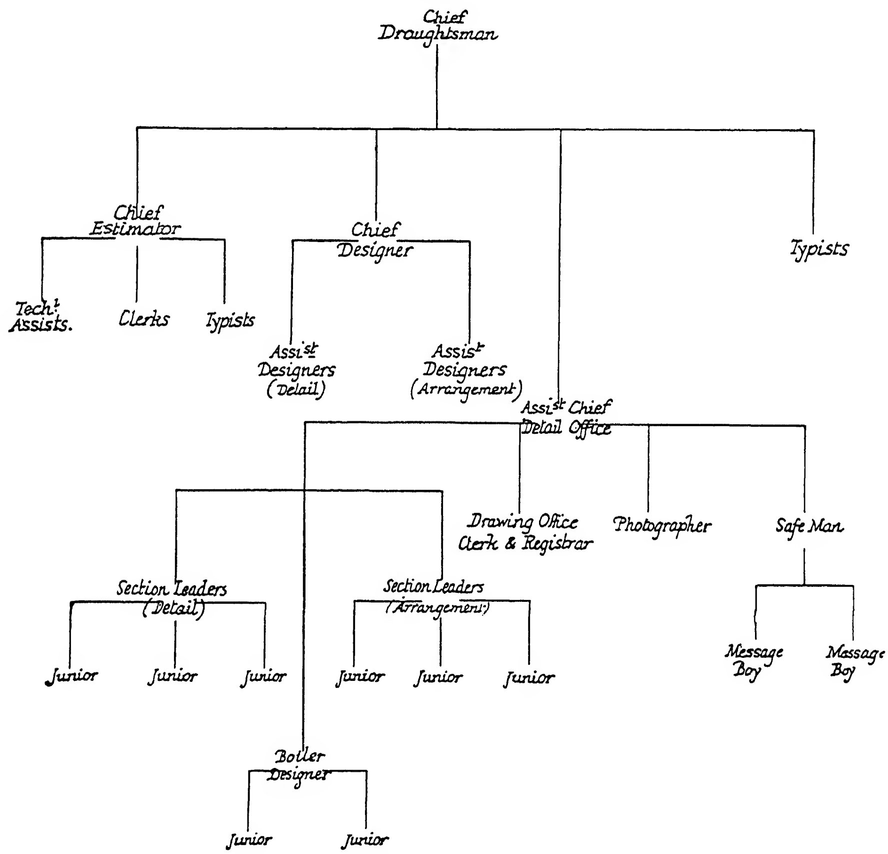


Fig. 16.—Relationship of Officials

although they do not enter into the daily routine of drawing-office work, they can be quite justly considered under the heading of organization.

One is the question of apprentices' entrance to the drawing office. From the nature of things, no universal system of recruiting drawing offices exists, nor is any standard of efficiency and ability demanded for full membership of the profession, although it is obvious events are moving in that direction. The day is possibly much nearer than many people suspect when draughtsmanship will be a profession like medicine, the law, accountancy, &c., in which qualifying examinations are necessary.

A practice, in some of the leading firms at present, is to staff the drawing

office with men selected as a result of an examination held by the firm. Where this course is adopted, the examination is confined to the firm's own apprentices who have had at least two and a half years' shop experience. Those who receive the highest marks come up to the drawing office if their works record is satisfactory, and this policy ensures a leaven of practical experience in the drawing-office staff.

Design of the Drawing Office.—Another point of organization which

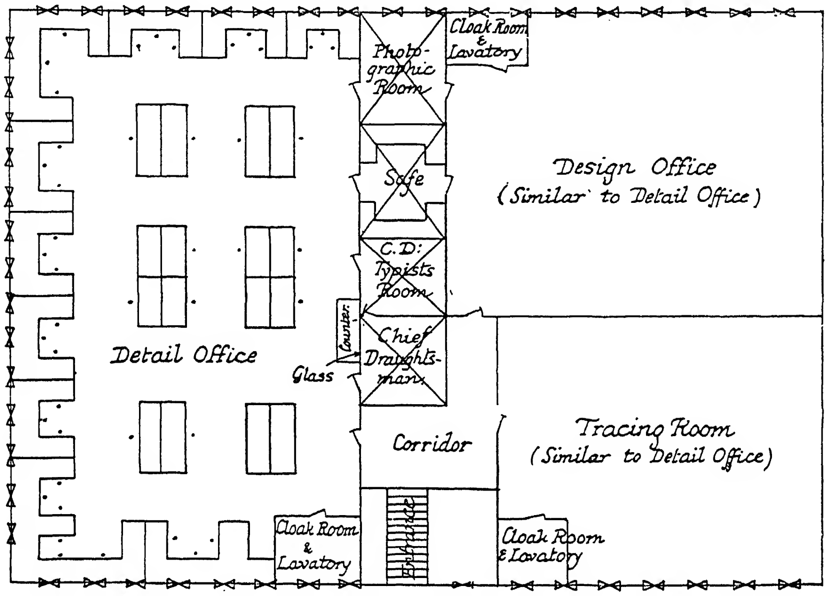


Fig. 17.—Arrangement of Offices

is worth consideration is the disposition of the various drawing-office departments. It is advisable to have them all on one flat, if possible. Certainly all should be in close proximity, and the chief draughtsman's room should be in a central position and easily accessible to all departments. A very satisfactory arrangement is shown in fig. 17.

The method of arranging the boards, the question of how they shall face, and how the light shall come in, the convenience of lockers, the places to lay drawings, the height and position of them to entail minimum fatigue, &c., must all be carefully considered.

PATTERN-MAKING

BY

JOSEPH HORNER, A.M.I.Mech.E.

Pattern-Making

Introductory

THE CRAFTSMAN

The work of a competent pattern-maker is both exacting and comprehensive. He must be skilled in woodwork, an accomplishment which he shares with the carpenter, joiner, and turner, who, however, may not understand how to construct patterns that will deliver from the sand, how to economize in material and avoid the employment of complete patterns by the substitution of skeleton-like structures, how and when to use sweeping boards, sectional pieces, or cores.

He has to know the best methods of countering the effects of the damp sand on porous timber, by the judicious employment of open joints, of segmental pieces, and of framed structures of many kinds.

He has to be fully conversant with the different systems of moulding —green and dry sand, and loam—and core-making in all their branches, and with the handling of light and heavy work. It is necessary to be familiar with the evils that result from shrinkages in unequally proportioned castings.

He is primarily responsible for the methods of moulding (since he has to determine how patterns shall be constructed for the mould joints), for ramming and delivery, and for the determination of upper and lower faces for pouring.

An intimate acquaintance with the operations of the machine-shop is necessary, as machining allowances vary considerably in different classes of castings, while the variations that occur in similar pieces are often large, due to the presence of hard cores, the straining of top-boxes, the absence of risers, and the differences between the results that are associated with the practice of hand-rapping and delivery and machine-moulding.

Elementary knowledge of arithmetic and geometry are required for the estimation of weights and the laying out of work. In all shops some men have to specialize in toothed gears, or in motor-work, or marine-castings, in plating metal patterns, in odd-side work, and so on. In truth, the craft of the pattern-maker is a many-sided one.

CHAPTER I

The Elements

Pattern-work includes two very broad aspects, that of the method of moulding to be adopted, and that of the actual construction. It is necessary to determine the first before the second can be proceeded with.

1. METHODS OF MOULDING

Castings may be made from (*a*) complete patterns, (*b*) incomplete or skeleton patterns, (*c*) loam patterns, (*d*) moulds swept directly in loam.

(*a*) *Complete patterns* are those whose shapes, except for cored portions, are identical with their castings. With the employment of these, many side-issues are involved: the directions of their jointing; the amount of shrinkage allowance and taper; the adoption of middle parts, loose pieces, and drawbacks or false cores; and the formation of internal portions by self-delivery or with independent cores.

(*b*) *Incomplete patterns* are made of strips or frames that have the out-and-out dimensions and the main contours the same as for their castings, but which leave interior spaces to be completed with sand cores, or with strickles. The object here is to economize timber, and incidentally to lessen weight.

(*c*) and (*d*) *Loam patterns*, and *moulds swept out in loam* are only used for circular bodies, so that flanges, bosses, and brackets must be prepared in wood as complete pattern elements and attached to the main pattern or set in the loam.

On the pattern-maker falls the responsibility of deciding by which of these methods the pattern-work and the moulds are to be made. In many cases the most suitable method is self-evident to a man with experience. Full patterns are always made for work of small and medium dimensions. Skeleton patterns, those of loam and loam moulds, have preference for very large articles, but subject in a measure to the number of castings required. A single casting, though of medium dimensions, would seldom have a full pattern, provided its shape were suitable for skeleton construction or sweeping; a large one, if repeated in considerable numbers, would. The problem always is just one of the relative costs in the pattern- and moulding-shops. A large pattern is expensive, but so is a large loam mould, for which numerous attachments may have to be prepared. It will often happen therefore that a quantity of castings of large dimensions can be more cheaply made from a skeleton pattern, perhaps from a complete one, than from loam moulds or loam patterns. In such a case the moulder has a grievance if the pattern-shop saddles him with unnecessary expense in order to lessen the costs of its own department.

(*a*) **Complete Patterns.**—In these, the first question that arises is that of the direction or directions of jointing the mould, with the usual though not necessary concomitant, that of jointing the pattern similarly. This very often admits of alternative solutions. In a fair number of instances, only one is practicable, though others may be possible if the cost of moulding is overlooked. The best way to approach the subject is to consider the simple elementary geometrical forms which are constantly recurring.

Jointing.—All moulds, except the relatively very small number which are "open", comprise bottom and top portions, included in bottom and top box-parts ("drag" and "cope"). An exception occurs in bedded-in moulds, for which the bottom box is not required. The jointing between top and bottom is determined by the facility afforded for delivery of the pattern, with the least risk of damage to the mould, and bearing in mind too the extent of subsequent details of finishing, coring, and of pouring, and the disposition of upper and lower faces. This latter consideration is most important when tooling enters into the case, since machined portions must be free from specks and blowholes. In general, if one portion is of greater depth than another, the deeper section goes in the bottom. The reason is that it is much better to withdraw a pattern from a bottom mould than to lift the top sand off the pattern. This is not always necessary, because when a top box-part is turned over, and the pattern parts along the joint, the upper portion can be left loose from that below, to come up with the top sand, and be withdrawn after turning over.

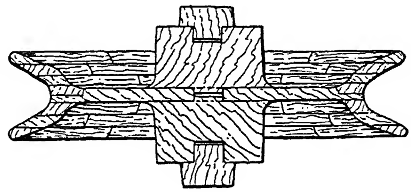


Fig. 1.—Pattern of Sheave Wheel built up

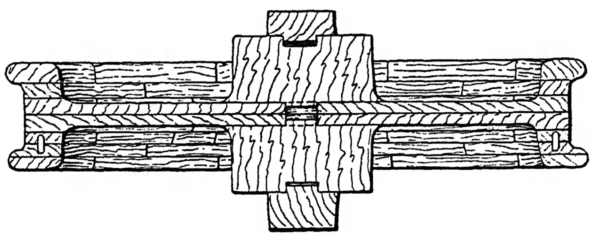


Fig. 2.—Pattern of Trolley Wheel built up

Elementary sections that deliver well are illustrated in many subsequent diagrams. The patterns may or may not be jointed along the same planes. Very often they are not; seldom in those of small dimensions used by brass moulders, because dowels work loose with usage, and the edges of the pattern parts overlap. When unjointed, the moulder makes the joint face, guided by the eye alone, or, in repetitive work, some form of joint-board, odd-side, or plate is provided.

In many instances, the pattern joint cannot coincide with that of the mould (fig. 1 and fig. 2 are typical examples). The patterns must have divisions to permit of withdrawing them from the moulds, but the joints of the latter do not coincide with those of their patterns. In the examples (figs. 1 and 2)

the mould joints are made along the centres of the convex edges, but the pattern joints are elsewhere.

Taper.—The deeper the mould, the more difficult is the pattern to withdraw and the greater the care that must be exercised to avoid disturbing the sand. The first inch or two is the stage at which fracture of the sand is most likely to occur. After the pattern has been loosened by rapping, and drawn slightly out of the sand, the principal care necessary for the remainder of the lift is to keep the pattern level, the difficulty of which increases directly with area. Slight rapping is continued until the pattern, by reason of its taper, has cleared the encircling walls of sand. Taper or draught therefore assumes much importance. Its amount varies widely. Some patterns have a large amount, in localities where it does not interfere with the fitting of parts, as on the outsides of deep bedplates, of sewer boxes, of machine frames, or of stiffening-brackets. No rule can be stated to meet all cases, but common practice is to give $\frac{1}{8}$ in. to $\frac{1}{4}$ in. per foot of depth.

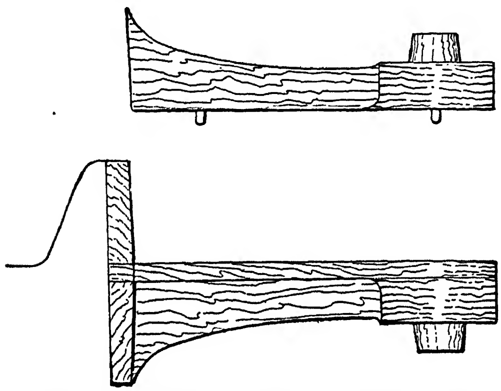


Fig. 3.—Rib and Boss dowelled to come with Top Box

Loose pieces.—These are a particular provision, made to ensure free delivery of portions on pattern sides, without making down-joints. In some cases they afford alternatives to coring and to drawbacks or false cores. In others, as in copes, pieces are often left loosely on the main pattern (figs. 3 and 4) in order to permit of their being taken out of the mould after turning the cope over in preference to lifting the mould off them. In the latter case, the alternative is to impart as much taper as is permissible to the portions that come in the top, and to avoid keen edges and angles there. In a sheave wheel the convexity of the internal rim (fig. 1) provides for a free delivery. In a trolley wheel, internal taper and a well-rounded edge are necessary. Top bosses are almost invariably left loose, unless they are very shallow. Thin facing pieces and core prints are fast, but these have well-tapered edges.

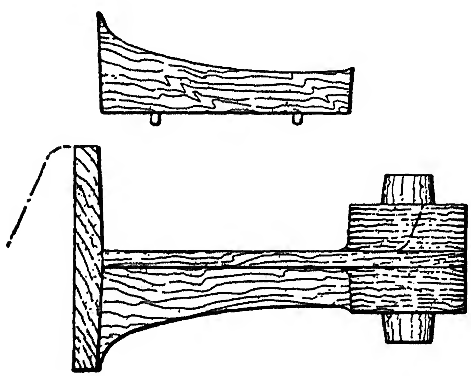


Fig. 4.—Rib dowelled to come with Top Box

Generally, when loose pieces are visualized, the most frequent case of those attached to the vertical sides of patterns occurs to the mind. In the

typical example (fig. 5) the top flange is fast to the pattern, but the rib below and the middle strip must not be (apart from the employment of a drawback plate). Loose pieces are located during ramming, either with skewers or with dovetails, the first-named being removed during ramming, previous to the withdrawal of the pattern.

Obviously, before a loose piece can be drawn inwards, there must be an open space large enough to receive it. If, in fig. 5, the pieces have to be drawn into the narrow space left on the withdrawal of the main rib, they must be thinner than the space thickness, as is the case in A. But the bottom strip in C is thicker, hence it must be divided into two or three thicknesses, one to follow the other. Since the pricker has to be inserted diagonally (B), getting the pieces out of so deep a space is troublesome, and no mending-up or cleaning can be done if the sand breaks down. But the conditions are altered if the interior has to be taken out with cores, or if, though rammed wholly in green sand, the ramming is done on a grid that permits of the removal of the interior mould. Ample space is then left, into which strips of greater width than those shown can be withdrawn. But even then there are limitations to the widths that can be dealt with in this manner, where fracture of the sand and convenience of cleaning and blackening have to be considered.

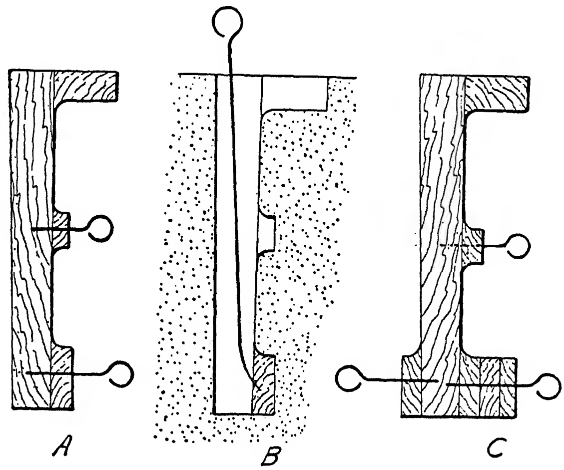


Fig. 5.—Loose Pieces

Drawbacks or false cores.—These avoid this awkward method of withdrawal, but they have a vastly wider scope. They are either grids or plates on which outer portions of moulds are rammed, to be lifted bodily away from the pattern, to be replaced and reset accurately by some form of joint between the plate, or its sand, and the sand in the main body of the mould. This is capable of very extensive applications, since there is no limit to the width of the encircling portions that can be carried thus.

Internal portions, Cores.—The conditions that control the delivery of internal parts differ from those of external. Thus, it will be obvious that depths and diameters are related. A shallow hole will deliver satisfactorily, though it has but a slight amount of taper. A deep hole of the same diameter will not, and therefore it must be taken out with an independent core. Frames of large dimensions may be regarded as patterns having large holes, relatively shallow. They deliver freely as well within as without, and they are tapered

by the same amount. The question of coring scarcely arises here, but it does in all cases where interiors will not deliver.

The plain interior of a casting, made by ramming sand within a pattern which is the exact replica of its casting, may be termed a core. But the accepted meaning of the term is, a body of sand, generally dried, rammed in a box distinct from its pattern, and inserted, and located in the mould by the impression of a core print attached to the pattern.

The alternative of coring an interior to making the pattern like its casting arises. In the majority of instances no doubt exists. No intricate shapes can be delivered. These must be rammed in a separate box or boxes, and inserted in the mould. In some instances it is more convenient to make cores than to self-deliver. In a fair number of cases a core is preferred, because, using prints, a stronger pattern can be constructed than if the timber

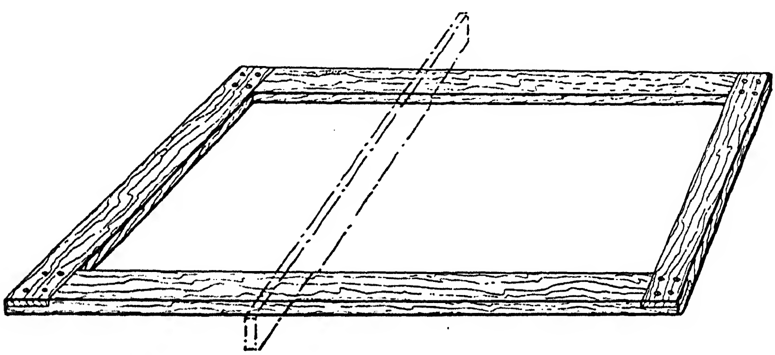


Fig. 6.—Skeleton Frame united with Halvings, with Interior Strickled

were cut away to allow the interior to deliver. Lastly, projecting portions are frequently cored over in preference to making a joint in the pattern, or " down-jointing ", or to employing loose pieces or drawbacks.

(*b*) **Skeleton Patterns.**—Patterns of large dimensions, and those of moderate sizes, when they are of shapes that would require considerable quantities of timber and much tedious cutting, are not made of solid, continuous stuff, but are of more or less open construction. The numbers of moulds required count in this scheme, so that while a skeleton pattern might be used for a few castings, a complete pattern would be more economical for large numbers.

The open frame (fig. 6) is the simplest example of the skeleton pattern. Narrow strips jointed at the corners provide the outside dimensions. The interior is strickled, or it is occupied with loose removable strips (fig. 7) for repetitive mouldings, the latter being better to ram the cope on than sand is. The same method is employed for plated portions that are curved in outlines (fig. 8), but with increased economy, because more timber and labour are required for working these than for plane frames. Here the strickle may be used, or strips be fitted at intervals to form a discontinuous guide, the spaces between the strips being filled with sand, to be rammed on. This method

is extensively adopted for large cylindrical bodies, which would be most costly to shape in solid timber, and be very heavy to handle.

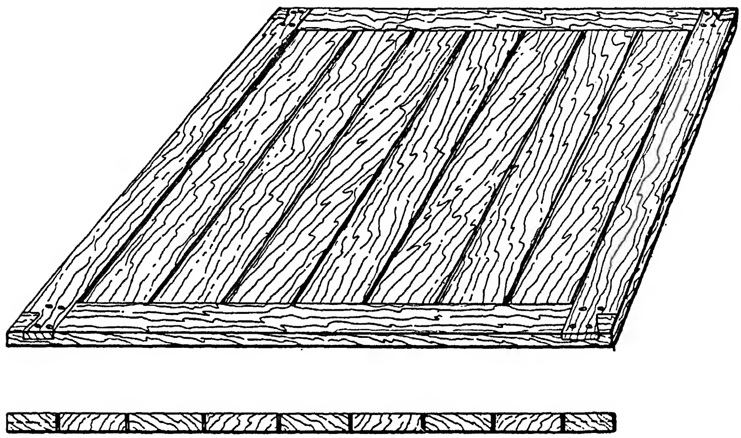


Fig. 7.—Skeleton Frame with Dovetailed Corners, and Interior occupied with Loose Boards to Ram upon

(*c*) **Loam Patterns.**—These (fig. 9), of cylindrical form, are swept on bars when they are too small to be swept in loam moulds on bricks, and

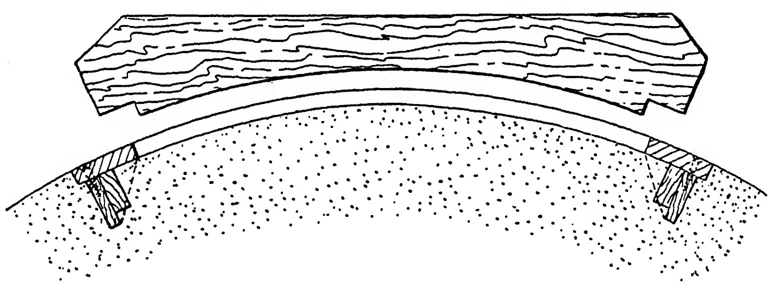


Fig. 8.—A Curved Tank Plate with Interior Strickled

too large, having regard to the number of castings required, to bear the cost of timber and labour. The field for their employment is thus rather re-

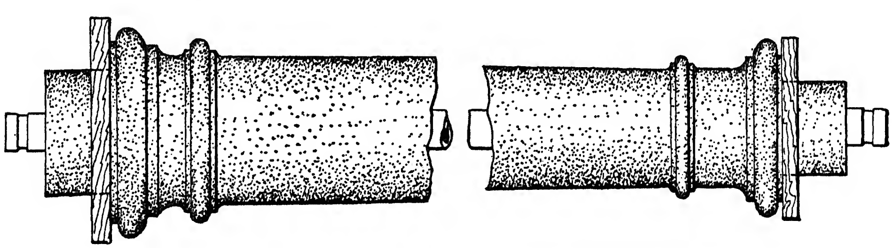


Fig. 9.—A Pattern Column swept in Loam, with Flanges of Wood

stricted. They are awkward to handle, being heavy, and do not deliver cleanly from the sand, especially in the cope, because their surfaces are rough,

and they are unjointed. All non-symmetrical fittings, as brackets, feet, bosses, and flanges, if large, are prepared separately in wood, and attached to or laid on the loam pattern. A large number of moulds can be taken from it, since it is hard, and its surface is protected with a coat of hot tar. Among the articles commonly made thus are cylinders, e.g. for hydraulic machines, for Corliss engines, for large gas-engines, and for pumps. Allied to this work is that of strickling patterns of bend pipes in halves. The loam is swept on grids; and flanges, feet, or other attachments are prepared in wood and fitted.

(*d*) **Swept Moulds.**—Moulds are swept in green sand and in loam to avoid the expense of complete or of skeleton patterns. The scope of the first is limited because the fragile character of green sand does not permit of deep sweeping. That of the second is very extensive, and is practically the only method available for very large cylindrical moulds. In some details where contours are irregular and unsymmetrical, loam is laid and worked against pattern parts of wood embedded in it. But the main moulds are swept to their symmetrical profiles with boards attached to a central revolving bar, set concentrically in a step bearing, and their main cores are swept on the same or a duplicate bar.

From these elements we turn to the consideration of the most suitable methods of pattern construction.

2. PATTERN CONSTRUCTION

The pattern-maker's craft differs in many ways from that of the carpenter, joiner, and wood-turner. The first and chief contrast lies in the necessary provisions that have to be made for delivery, taper, and the other matters instanced in the preceding division. In addition, measures have to be taken to minimize the effects of the severe and destructive treatment to which patterns are subjected. It is that of insertion in wet sand, of rapping, and delivery, alternating with storage, and what is as injurious, the alterations that have to be made in many patterns from time to time. And, in all but highly standardized work, wood alone is used, yellow pine mostly, soft and porous, and mahogany to a limited extent for small articles.

Very broadly, pattern construction falls within three great groups: plane areas, cylindrical articles, and circular work.

Plane Areas.—In dealing with these the aim is to lessen the widths of individual pieces to relatively narrow strips in order to localize the expansion due to moisture and the shrinkage consequent on storage, which regularly alternate. The solid glued-up table tops and side-boards of the cabinet-maker have no analogues in pattern-work. Instead, wide pieces are always made with "open joints" (fig. 10), that is, a space of about $\frac{1}{8}$ in. or less is left between strips, to the extent of which they are free to expand when moisture is absorbed, so that the out-and-out dimensions of a broad width are not affected.

Since the edges of the open joints are not united, there is no cohesion between the pieces as there is when edges are glued, nor can the pieces lie

flat. The method adopted therefore is to drive into the adjacent edges tightly-fitting dowels, which prevent the faces from getting out of level. The strips are maintained in one plane by the attachment of flanges, ribs, or other pieces, as in fig. 10, or, if these do not happen to be available, then temporary battens are screwed across, the impressions of which are "stopped-off" in the mould. An alternative to this, which can be adopted when the plated portion lies horizontally, is to make an open frame, jointed at the corners, and to fill up the interior with loose strips (fig. 7).

Boxing-up.—This, except in narrow widths, is combined with open jointing. It is adopted in all rectangular sections that are too large to be cut from solid plank, and is the only way in which swelling and shrinkage can be avoided in these. Longitudinal strips are screwed to cross-bars, a single strip for narrow sections, several strips with open joints for the larger dimensions.

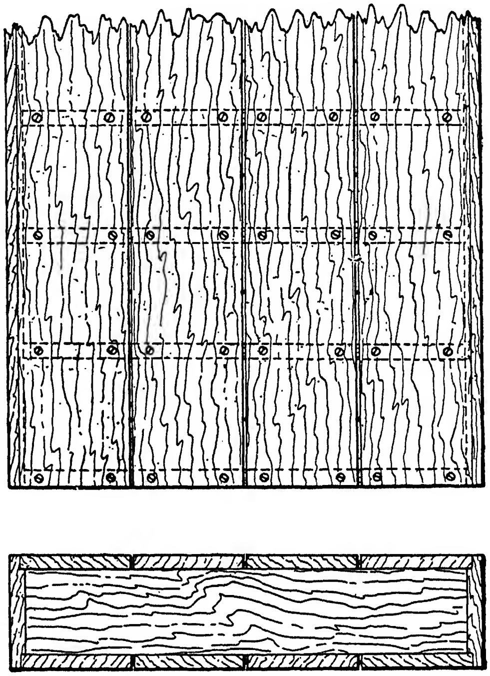


Fig. 10.—Portion of Boxed-up Bed, showing Open Joints and Cross-bars

In these constructions the vertical pieces should occupy the entire depth of the pattern, as in fig. 11 A, B, and should never lie between the top and bottom plates, as in fig. 11, C. The reason is, that the delivery of the first is clean, that in the second is not, because a very slight shrinkage of the strips produces lapping edges that tear up the sand. Also it is better to fit the pieces with a rebated shoulder (A) than to make abutting joints only (B).

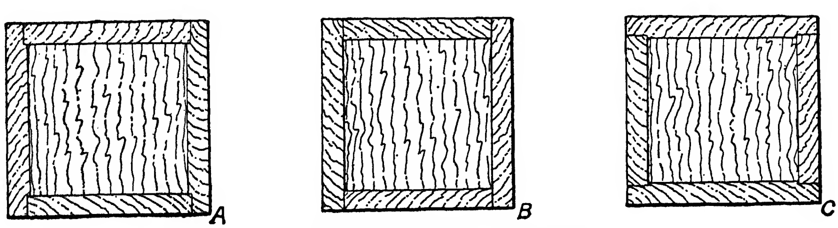


Fig. 11.—Right and Wrong Ways of Boxing-up

Cylindrical Articles.—These include engine cylinders, pump barrels,

pipes and columns, and work of which these are typical. Only when these are of small dimensions, say of 6 in. diameter and under, are they made in solid stuff, usually jointed along the central plane and dowelled. When of over this size the patterns are built up with narrow strips, glued on cross-pieces, located at short intervals—" lagging ". This method is adopted up to the largest diameters for which entire patterns of wood are constructed. As diameters increase, the number of lags is multiplied. In all cases they are very narrow to localize shrinkage, ranging within small limits, say from 2 in. in small bodies to not more than 5 in. in the largest. It is necessary to secure rigidity as well as freedom from changes of form. Strips must not be too thin, nor may the cross-bars be spaced very far apart. Proportions are governed by diameter and length. Subsequent drawings (figs. 34 and 35) indicate suitable proportions. Good close joints must be made between adjacent edges, and be united with glue. If the work is done carefully and well, and seasoned stuff used, the patterns will retain their accuracy for an indefinite period. There are details in the methods of construction that are dealt with in later sections, where examples of work are illustrated.

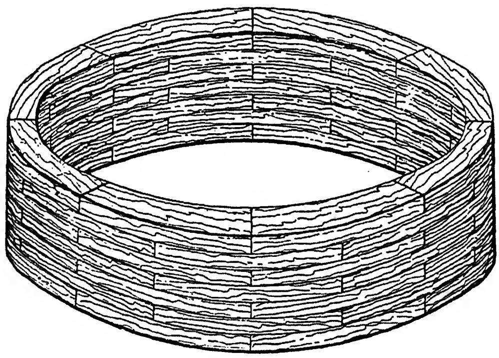


Fig. 12.—Ring built with Segments

Circular Work.—This is built up with sectors of circles—" segmental work ". Obviously, if rings were cut from solid material, they would shrink into elliptical forms, and fracture along the short grain. Built with sector pieces overlapping, " breaking joint ", they mutually reinforce each other, shrinkage is minimized, and the circular shape is maintained. (See Chapter II, Section 3.) To secure this result perfectly, it is necessary to limit the length and the thickness of the individual pieces. Those too long would shrink in width, and those too thick would shrink and lack something of reinforcement by other pieces. The maintenance of a judicious relationship between these proportions is necessary to secure permanence of form. This method of building-up is suitable alike for rings that are shallow or deep. The shallower the work, the thinner the sectors are. A thin flange of large diameter should not be built in less than three or four courses. Rings of

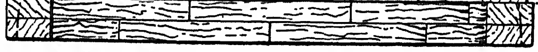


Fig. 13.—Semi-spherical Pattern built up

all sections are made in this way, parallel (fig. 12), bevelled, and semi-spherical (fig. 13). The pieces are glued singly, with carefully planed joints, checked with chalk. In general it is not necessary to reinforce the joints, but as a precaution wire nails are frequently driven in. When the section of a pattern is that of a cone, as in the rim of a bevel wheel, or has any curved outline, wooden pegs are preferable, because, if they should happen to come to the exterior, they will not damage the turning-tools.

Methods of Union.—The union of elements is in some respects peculiar to pattern-work, being due to the necessity of making alterations from time to time. The tenon and mortise joint is seldom used. Other forms of joints are frequently not glued, but screwed only. Unions of a more or less temporary character made with battens, the impressions of which are filled up in the sand, and do not appear in the casting, occupy a useful place in alterations. Very many alterations are made only partly in the pattern, being completed in the mould by the method of "stopping-off". One of the commonest joints is the half-lap, used for uniting flat strips. It is either a plain half-lap fastened with screws only, when there is a probability of future alterations being called for (fig. 6), or, if permanent, the dovetail form is cut (fig. 7), and the joint is both glued and screwed. Screws occupy a larger place in pattern-work than in the more permanent methods of the joiner. They take the place of tenons and mortises and dovetails in the attachment of parts.

Dovetails.—These are employed chiefly for the corners of deep open frames that deliver their interiors, of which sewer boxes are typical, and for loose pieces, as an alternative to the skewers. Their use is generally restricted to standardized work. They are safer than the skewers, since these afford but a doubtful indication, by their small holes, of the position of a loose piece if mislaid.

Dowels.—These play a large part in pattern-work. They include the tightly fitting dowels used in open joints, and those loosely fitting in one piece, in the joints of patterns that are divided for delivery between bottom and top parts (figs. 3 and 4). These are of wood or, for permanent work, of brass or malleable-cast iron.

Angles, Fillets, or Hollows.—These are peculiar to pattern-work, being employed to fill up re-entrant angles that would, without them, invite fracture in the castings. They should never be omitted. They are made of wood, leather, or soft metal, to be bent round curved portions. Illustrations of all the elements here noted will occur in the subsequent sections.

3. CORE PRINTS AND CORE BOXES

Core Prints.—The function of a core print is to locate, by the impression which it leaves in a mould, the exact place for the insertion of a core. There are exceptions to this general statement, since some large cores are set without print impressions, as when moulds are made from sectional and skeleton patterns. Also, when portions of metal are cored over, in

order to avoid the employment of loose pieces or of drawbacks. Core prints fall under two fundamental types, the " round " and the " drop " or " pocket " forms.

Round Prints.—These are set either vertically or horizontally. The first-named have taper or draught, the second are, as a rule, parallel, invariably so when a pattern and its prints are jointed longitudinally through the centre to be withdrawn from cope and drag. They are tapered when they are attached to bosses or pieces that have to be left loose and be drawn horizontally back into the mould.

Vertical Prints.—There is no recognized rule for the length or the taper of these. Both call for the exercise of judgment. As the diameters of prints are increased, their length or thickness *a* (fig. 14, A) is lessened re-

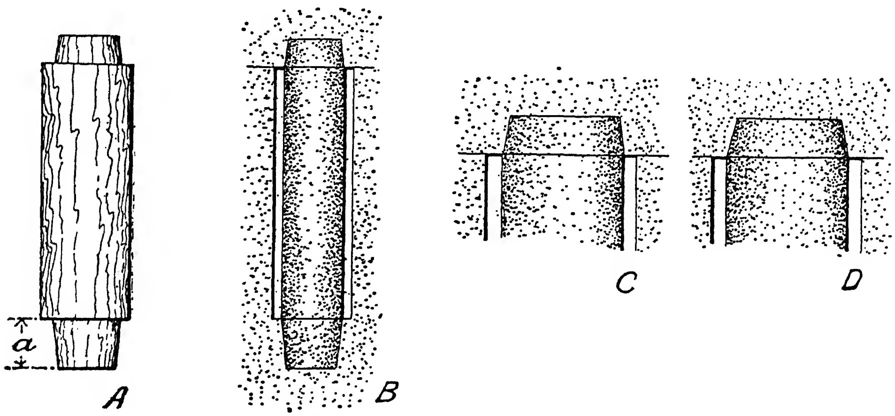


Fig. 14.—Vertical Core Prints, and Cores

latively, because the larger diameters afford better support to the core at the bottom than at the sides. A print for example 1 ft. in diameter need not be more than ½ in. thick, while one of 1 in. diameter will be 1 in. long. Up to about 3 in., lengths and diameters are about equal, beyond that the proportionate thickness lessens.

Prints are thinner at the top than at the bottom (fig. 14, A). Usually they need not be more than half the thickness, since they have not to support the core, but only to steady it against risk of lateral displacement during pouring (fig. 14, B).

Bottom prints may have from ⅛ in. to ¼ in. taper on the diameter. Top prints should have more, because the sand in the cope has to be lowered on the upstanding core, with risk of a crush if the taper is not ample. Often, to avoid this risk, the portion of the core that enters the print impression has an excess of taper, with the result that close contact does not occur until the cope is down to its bedding. (Compare C and D, fig. 14.) It is desirable in work that is standardized to put the taper in the core boxes. Ordinarily the moulder rubs the taper on the cores to match the print impressions, and this is a frequent cause of inaccurate setting.

Horizontal Prints.—Round core prints disposed horizontally, as in pipes, columns, and work of which these are typical, are not tapered. The lengths of the prints are about equal to their diameter in the smaller dimensions. As sizes increase, the lengths are relatively less. But they may never be very short, because in that case the weight of a heavy core would cause the sand to crush. In most cases the core is bridged between two horizontal prints. When it has to be supported from a single print impression the length must be sufficient to counterbalance the weight of the overhang of the core. But this is only necessary in those cases where no assistance can be obtained from chaplet nails.

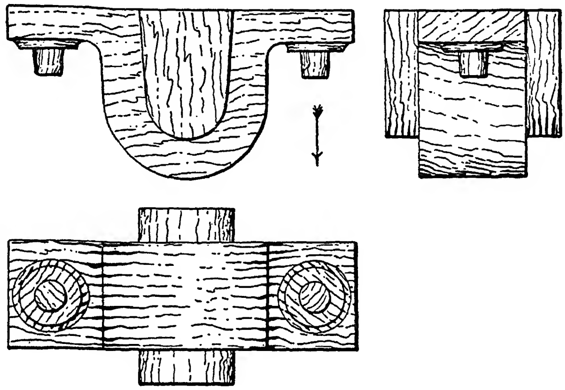


Fig. 15.—Drop or Pocket Prints

Drop or Pocket Prints.—These (fig. 15) are employed for horizontal cores when the joint of the mould does not coincide with the centre of the core print, as it does in the pipe and column types of patterns. Even then in some cases round parallel prints are attached, and a sloping "down-joint" is made to the centre. Or round, tapered prints are skewered on loosely. But these are exceptions to the usual practice.

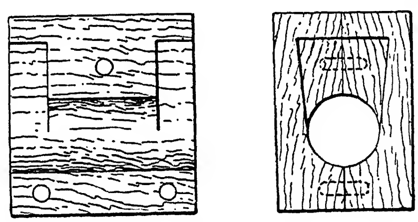


Fig. 16.—Core Box for Stopping-over Drop Prints

The drop print only indicates a portion of the outline of the core to be inserted — the lower part, semicircular for round cores, other shapes for other forms. The portion of the print above the centre is tapered to deliver, but its impression is filled up, following the insertion of the core—"stopping-over". This is done by the moulder, or, in standard work, the core is made in a box (fig. 16), which includes the stopping-over portion in addition to the actual core. The thicknesses of these prints are similar to those of the plain horizontal kind. Thin prints will not provide sufficient support in the sand to sustain the weight of a core without risk of crushing.

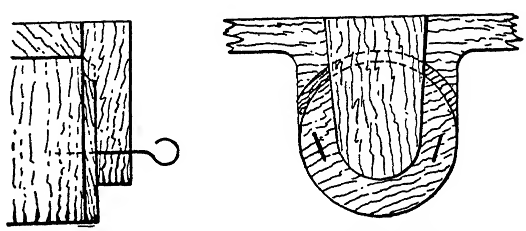


Fig. 17.—Boss Facing covered with Drop Print

The fitting of drop prints is often associated with the presence of boss facings which have to be left loose (fig. 17). These are cut to fit round the print, or the print is notched to fit over them. The portion of the boss that is covered by the print has to be made good in the mould during the stopping-over (fig. 18), or, for permanent work, it is put in the core box.

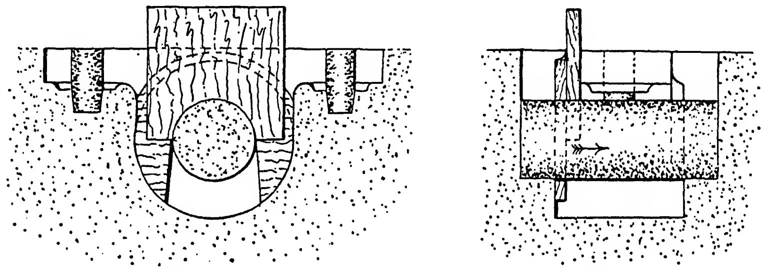


Fig. 18.—Stopping-over a Core with Boss Facing in Mould

Core Boxes.—When determining the forms of these, similar methods and precautions have to be observed as in the construction of patterns, with regard to freedom of delivery, taper, loose pieces, and so on. In addition there is the excess length necessary for the location of the cores in the print impressions. Often a main core will contain prints, the impressions of which will serve for the location of other cores. Box portions must generally be taken apart to permit of the removal of the core, so that they are only held temporarily with dowels, clamps, or screws. The subject of core-box work is therefore nearly as extensive as that of pattern construction.

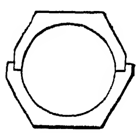


Fig. 19.—Iron Box for Round Cores

Standard boxes of iron have their halves fitted with tongues and grooves (fig. 19); those of wood are very similar (fig. 20). The ends of rectangular boxes may be retained in place with blocks screwed against the sides, and the sides may be screwed to the ends (fig. 21). This entails loss of time in removing the screws as often as the sides have to be taken away from the core. Clamps of wood (fig. 23) or of iron are to be preferred. The sides of long boxes will become rammed outwards, with consequent enlargement of the core, unless they are retained about the centre with a bolt (fig. 22) or with a clamp. The fitting of ends into shallow grooves (fig. 22) is to be preferred to their abutment against end blocks. Frequently the interior of a rectangular frame is occupied with contour fittings. In one example shown (fig. 23) for making one of the numerous cores for a turbine ring the blocking of yellow pine is lined with mahogany to favour durability in service. Here the actual width of the turbine ring that of the curved strip which represents the metal separating three tiers

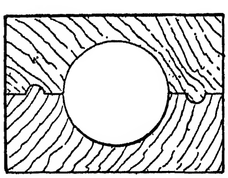


Fig. 20.—Wooden Box for Round Cores

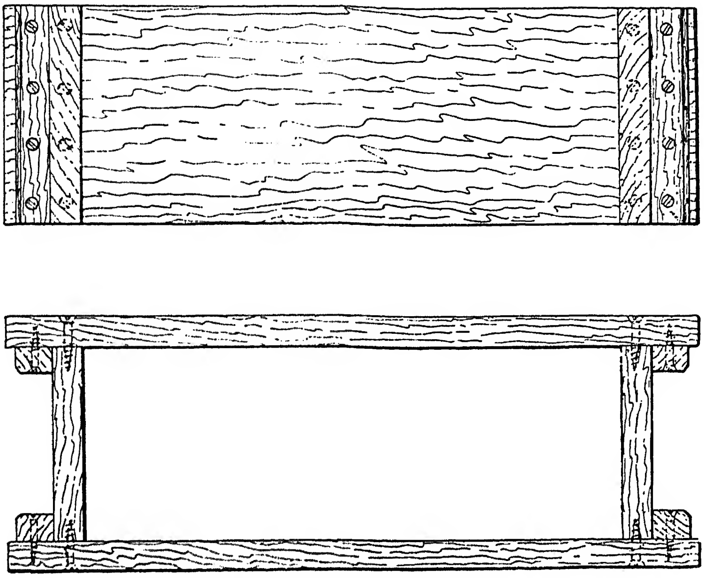


Fig. 21.—Core Box with Joggles

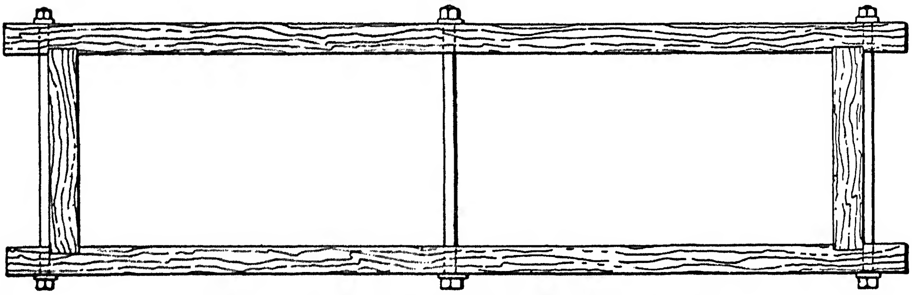


Fig. 22.—Wooden Core Box, with Ends Recessed, and Bolts

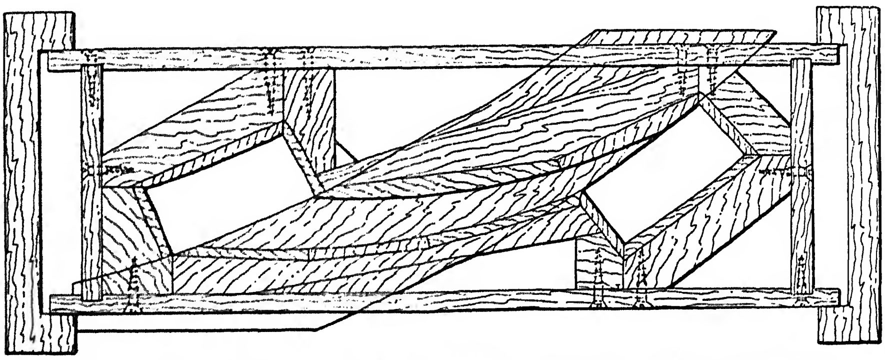


Fig. 23.—Core Box for Turbine Rings, with Recessed Ends, Clamps, Internal Blockings, and Mahogany Facings

of buckets. The supplementary open spaces are equivalent to the extra length allowed on cores to enter print impressions. But in this case the cores are simply set to lines described on a levelled bed of sand, and, mutually abutting by their supplementary portions, they complete the ring.

Plain, rectangular boxes are rammed on a core bench. A bottom board is necessary when bosses and other fittings have to be located correctly. The sides fit this with dowels or with strips on the board. Often one or

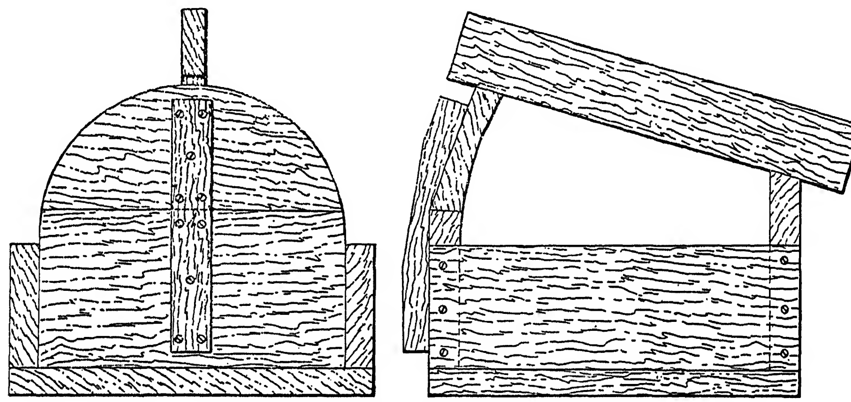


Fig. 24.—Core Box with Strickle for Curved Portions

two faces of a core are curved. Then, when practicable, strickling is resorted to (fig. 24), as it is also for the upper plane faces of cores. This economy in curved portions is that due to the saving of timber and of the time occupied in shaping it to the curves.

CHAPTER II

Examples of Work

Pattern-making includes many departments. The work done on patterns for a brass foundry is wholly different from that done on patterns for the heavier castings of the marine engine, the locomotive, and the larger types of pumps, while the making of core boxes for gas and automobile cylinders calls for special ingenuity and skill. The construction of patterns for cranes, gear wheels, pipes, and columns, each enlists the services of men who have developed into specialists. In every large shop certain groups of patterns go to men who seldom handle anything else. But a trained, intelligent man is, or should be, able to take up any branch of his trade when required to do so. The principles that underlie the practice are unchangeable. It is from this chiefly, the general standpoint, that the subject will be regarded in this section.

1. CYLINDRICAL WORK

There are certain groups of patterns which possess one feature in common, that of being jointed through the longitudinal centre. Pipes, columns, and cylinders of all kinds are typical of a very large number of patterns jointed thus.

Turning Patterns in Halves.—Patterns, being divided for convenience of moulding, are jointed and dowelled before they are turned, since it would be inaccurate to saw through solid patterns. Being dowelled, they have to be secured during turning with dogs (fig. 25), screws (fig. 26), or centre plates (fig. 27). Dogs are driven into the ends in small and large work alike, in the latter, as an additional reinforcement to the centre plates. For very light articles the dogs alone may suffice, the centring being done directly in the wood instead of on plates. Screws are generally used for very light pieces. They are inserted near the ends, in supplementary portions to be cut off after the pattern has been turned. If one or two must come also in the body of the pattern, as when it is of considerable length, the heads must go in countersunk recesses, to clear the turning-tools, and the holes are filled up subsequently. Centre plates, smaller and larger, are used very generally, not only to secure jointed patterns, but also to receive the lathe centres in those that are solid, as these wear the soft woods when turning is being done, causing the pattern to run eccentrically. The plates are made of iron or brass, and are formed in the smallest sizes like dogs, to be driven in, but in the larger sizes they are attached with screws or with nails.

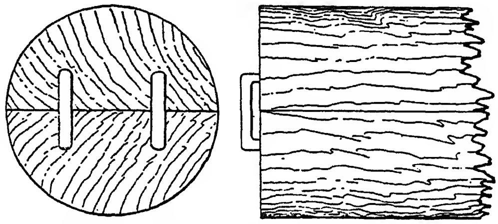


Fig. 25.—Clamping Pattern Halves with Dogs

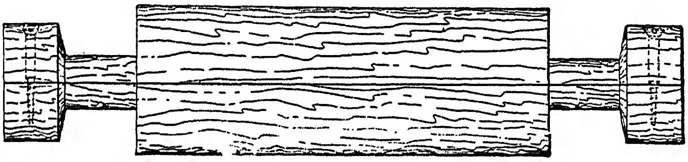


Fig. 26.—Securing Pattern Halves with Screws

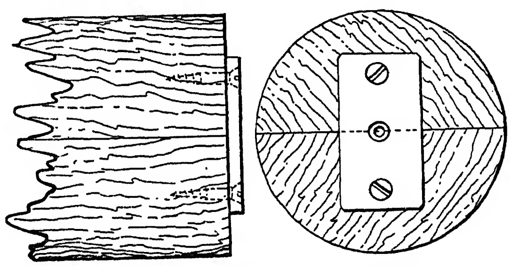


Fig. 27.—Securing Pattern Halves with Centre Plates

In some cases it happens that jointed pattern portions are less than semi-

circles, as when boss sections have to be fitted on plates or webs. Then a piece of the web thickness is interposed before the boss is turned, and is afterwards thrown away.

Flanges and similar attachments are turned in halves, usually dowelled, and then attached to their bodies. They are held on the face plate with screws inserted through the plate from the back. The hole is bored entirely through, or it is recessed, leaving a portion to be removed with the band-saw.

Pipe Patterns.—Pipes and columns have several cardinal aspects in common. Both are jointed longitudinally, dowelled, and moulded by turning over. Both are lagged when the smallest diameters are exceeded. Each has flanges and other attachments fitted. Loam patterns are used for those of large dimensions. Patterns are plated for quantities. For very large numbers, metal patterns, unjointed, are employed.

Pipe Patterns for General Service.—It is necessary to make use of this phrase, because, outside of the general shops, pipes are made by highly

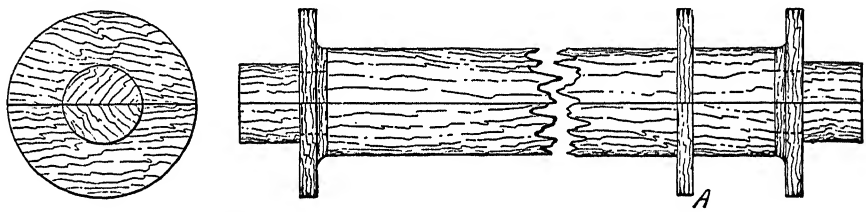


Fig. 28.—Pipe Pattern with Body Flange for Alterations

specialized methods. They are cast vertically. Metal patterns, collapsing core bars, and a number of special appliances, associated with the moulding, coring, and casting, are used. In America large numbers of pipes are made in permanent iron moulds. The methods of making bend and tee-pipes are similarly specialized.

In the general shops the outstanding feature is that pipe patterns have to be utilized not only for standard lengths, with flanges, sockets, and spigots of standard dimensions, but with slight alterations may have to be used for all kinds of odd jobs and make-up lengths. In these shops therefore it is customary to keep one set of patterns strictly for standard sizes, and a lot of odd lengths and nondescript pieces for occasional orders. The cutting and scheming necessary exercise the judgment of the pattern-maker, and very much has to be done with stopping-off pieces, which increase the work of the moulder. In the last case the pattern is not wholly like the casting produced, the shape of which is revealed by the stopping-off pieces supplied and the corresponding sectional parts put on the pattern.

Pipe flanges are fitted into recesses turned between the termination of the body and the core prints (fig. 28). A flange being retained correctly in its recess need not be screwed in place. For casting shorter lengths, a body flange A is screwed on, and this indicates the length at which the mould has to be stopped off. The stopping-off piece supplied carries the half-core print. Socketed pipes are stopped-off by providing an iron socket piece

that can be moved along the body of the pipe and screwed in any required position. As this carries the print, a stopping-off piece is not wanted.

When turning long pipe patterns, the correct diameter is set in at each end. A very light cut is taken about the centre, not quite down to the finished size, because of the spring and vibration present. The reduced section is then embraced by a "steady" mounted on the shears of the lathe bed, and a rough cut is taken with the gouge from the centre to the ends. A flat is then planed from end to end, checked with a straight-edge, and rubbed with chalk or red lead. This serves as a guide to turning down intermediate sections, without the need of having frequent recourse to the calipers and straight-edge to check the progress of the work.

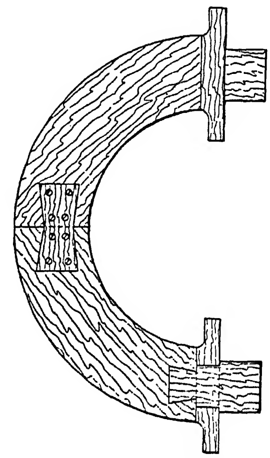
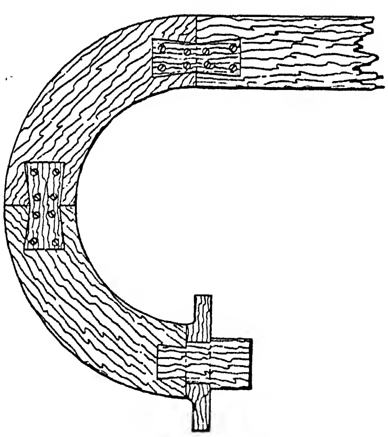


Fig. 29—Pattern for Bend Pipe of Small Radius

Bend Pipes.—These may be long pieces of straight pipe with a bend at one end, or they may be entirely curved. On the degree of curvature depends the method of their preparation. "Quick bends", those of small radius (figs. 29 and 30), are turned in halves on the face plate. Four quadrants being screwed to the plate by their joint faces, and turned, provide two complete bends. Bends of large radii are worked in halves by hand methods. From a rectangular cross-section a polygonal shape is cut, leaving only minute angularities to



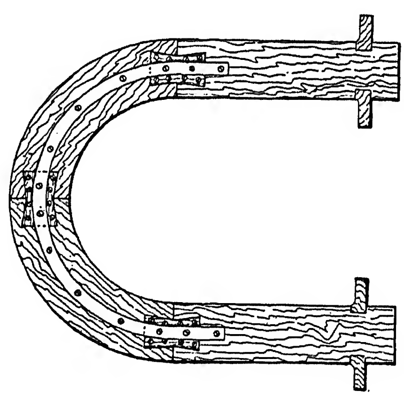


Fig. 30 Illustrations of Pipe Bends Fig. 31

be removed, to produce the semicircular shape, which is checked with a templet.

When bends are attached to straight lengths of pipe, abutting joints are used (figs. 30 and 31), secured with dovetailed pieces let into the joint faces and screwed. The same method is employed for uniting branch pipes at right (fig. 32) or other angles, as for tee-pieces. Sometimes a plate of iron

is used instead of a dovetail (fig. 33), or to reinforce dovetails (fig. 31). Abutting joints are reinforced with dowel-pins fitting tightly, and with screws put in diagonally. Flanges, sockets, and spigots are fitted as in straight pipes. and stopping-off is practised.

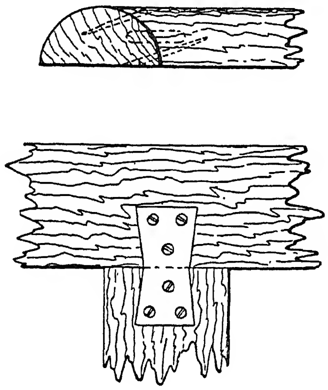


Fig. 32.
Pipe Joints at Right Angles

The larger pipes and bends, and those of awkward shapes, for which the demand is limited, are frequently moulded from loam patterns, for which the pattern-maker supplies strickles and fittings. As the principal work is thrown on the core-maker and moulder, the subject is reserved for treatment in the article on Foundry Work.

Column Patterns.—These are only made solidly when of small diameters, say not exceeding 4 in. or 5 in. Beyond these, and apart from quantity methods of moulding, they are always parted longitudinally along the centre and dowelled. Solid timber is rarely used when the diameter exceeds 6 in. or 7 in. The reason is that the stuff is liable to become convex or concave in the joint faces, and the pattern to lose its circular section. It is also liable to warp and curve lengthwise, an evil that results from the incessant wettings of the joint faces with the swab.

Patterns from about 6 in. in diameter upwards are, like the larger pipes, built with " lags " or strips of timber screwed on cross-bars (fig. 34) and glued to each other with longitudinal joint edges. No rules can be stated for the cross-sectional dimensions of lagging strips, nor for the spacing of the cross-bars. These are proportional to the diameter and the length of the column, but are never very thick nor very wide, since, as in segmental work, the object sought is to localize shrinkage as much as possible. The cross-bars must be set at distances sufficiently close to one another to sustain the lags bridged over them against the pressure of ramming. Thus the stiffness of the pattern must be secured without unduly increasing the timber sections. A little experience teaches the pattern-maker how to proportion these details, the relations of which are correctly proportioned in the accompanying drawings.

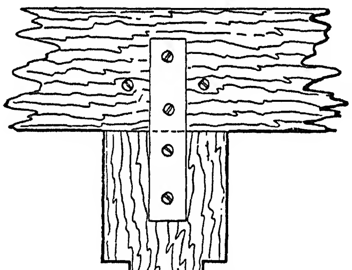


Fig. 33.—Iron Plate for Pipe Joints

When building up divided columns, the cross-bars for one half are laid down on a true joint board, and the lags are fitted to that first. They are planed on faces and abutting edges, the latter being chalked to show contact,

and corrected with the trying plane. Each is glued to its fellow, a man stationed at each end imparting a reciprocating movement to the lag about

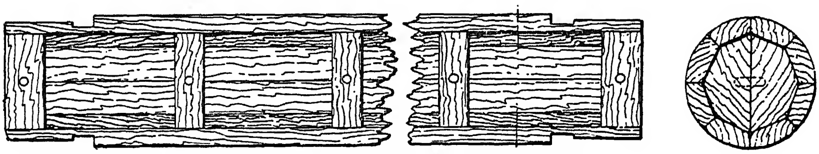


Fig. 34.—Construction of a Lagged Pattern

half a dozen times to work out the surplus glue. Iron dogs driven in keep the joint in contact until the glue has dried, and one screw is put in through each lag into each cross-bar. The heads of these are sunk in to permit of turning. When one half has been prepared thus, it is turned over, the other halves of the cross-bars are set in position by their dowels, and the lags for that half are fitted, glued, and screwed. The halves are united with centre plates, and the turning is done with hand-tools or from a sliding rest. Done by hand, the same method is pursued, and time saved, as in the turning of pipe patterns. A steady is used to prevent sag about the central portions.

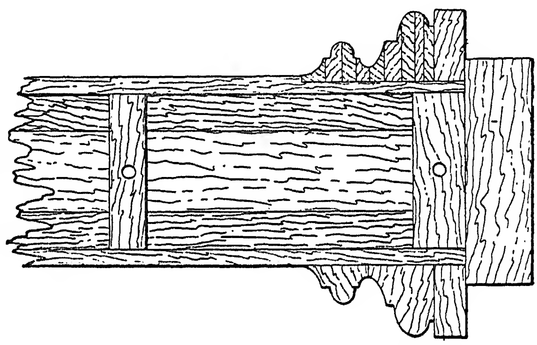


Fig. 35.—Alternative Methods of Fitting Mouldings

Column Fittings.—All columns have flanges, with or without mouldings. These are nearly always prepared separately from the shaft, which is necessary, both to keep the thickness of the lags within reasonable limits, and to avoid short grain. Generally flanges, and frequently mouldings, are fitted into shallow grooves turned in the shaft (fig. 35, top), and with the grain running transversely. They are either glued-up in segments, the better way, or cut solidly and not recessed (fig. 35, bottom). In some cases it is better to glue blocks on the lags, and to turn the mouldings from these. The choice depends on the proportions of these supplementary parts.

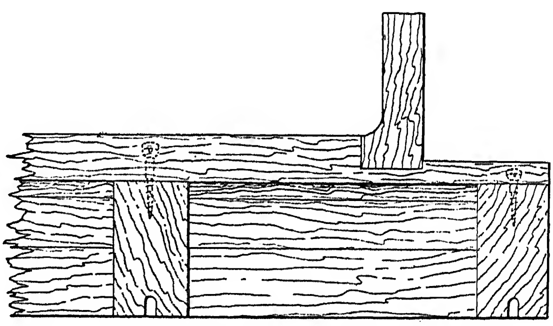


Fig. 36.—Shows Print Continuous with Lags

The fitting of the end core prints depends on the relative diameters of prints and shaft. If the difference is only that due to the thickness of metal in the shaft, prints are turned on an extension of the lagging (figs. 34 and 36). But if they have to core out a large moulding, then they are better fitted separately (fig. 35), the lags terminating with the moulding. When large square bases are fitted to columns, these are prepared separately and attached. The square prints being large, are boxed up and screwed against the end of the column and its flange (fig. 37).

Fluted Columns.—The problem in these is that of providing for delivery of the undercut flutes. The pattern shaft is built with lags, having flats to receive loose strips in which the flutes are planed. The divisions

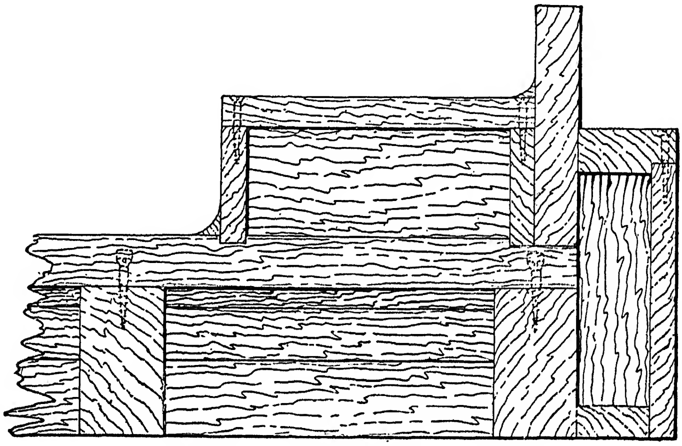


Fig. 37.—Method of Fitting a Square Base and its Print

between the strips are determined by the amount and direction of undercut. In the withdrawal the shaft is taken out first, then the loose pieces adjacent to the mould joint are removed, and finally those in the bottom. This will be clear from the section (fig. 38).

In the construction of these patterns, the internal shaft, the body which forms a backing for the fluted strips, is prepared; the strips are attached to it with screws put in from within the body, to be taken out in the mould; and the strips are turned. The edges of the flutes are divided round and marked along, the strips removed, and the flutes planed. To permit of planing through, the end pieces where the flutes terminate are screwed temporarily. Fig. 39 shows a column section where the body is of cast iron made for permanent service. Metal screws hold the lags, being tapped into plates sunk in the flute strips.

The cores for columns are usually swept against the edges of boards, unless large numbers are required, when they are rammed in a half-box, each half-core being united to its fellow. In plain and moulded columns the whole of the core can be swept, including the enlarged portions for the mouldings. But if there is a large square base, as in figs. 37 and 38, or a

heavily foliated capital, cores for these sections must be rammed in boxes having a central print of the same diameter as the core for the shaft. This leaves a hole to fit over the latter.

Cylinder Patterns. — Most patterns of this class are divided longitudinally through the centre, notwithstanding the fact that they are in the majority of instances set vertically for pouring. An exception occurs in the largest cylinders, which are moulded vertically, frequently from skeleton patterns, or swept in loam. A fair number of moulds of medium dimensions are taken from loam patterns, which also are unjointed. Patterns of metal are used for highly repetitive castings in the smaller bores. With these exceptions, cylinder patterns are built with lags similarly to the pipes and columns just noticed. They have parallel prints for the main core, usually head metal, and flanges prepared separately from the body. All this is simple, plain work. The difficulties that occur in cylinder patterns and moulds are those associated with the preparation and the setting of cores, which increase with their number and tenuity, and are the most frequent cause of the rather high proportion of "wasters" that are produced in some foundries.

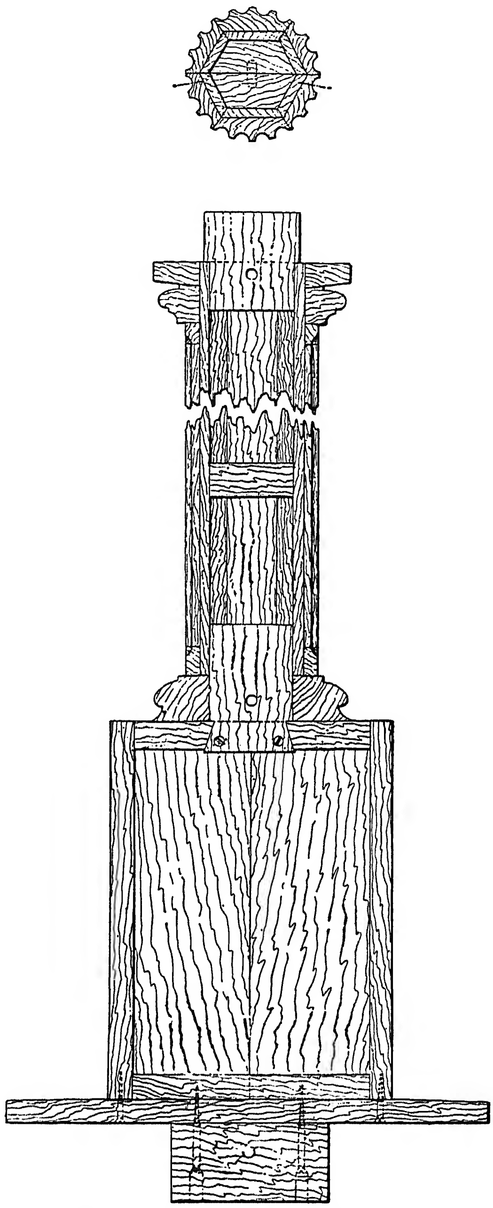


Fig. 38.—A Fluted Column with Square Base

Any cylinder, whether simple or complex, must be drawn to actual size on a shop board, with the machining allowances and the positions and dimensions of core prints included, in all aspects and sections. On and from this the pattern parts and core boxes are tried and checked as the

work proceeds. Some pattern parts have to be left loose, fitting with dowels or skewers. The locations of these are determined by the method of jointing and moulding adopted, this being settled by the pattern-maker. In some cases, alternatives present themselves, in others only one method

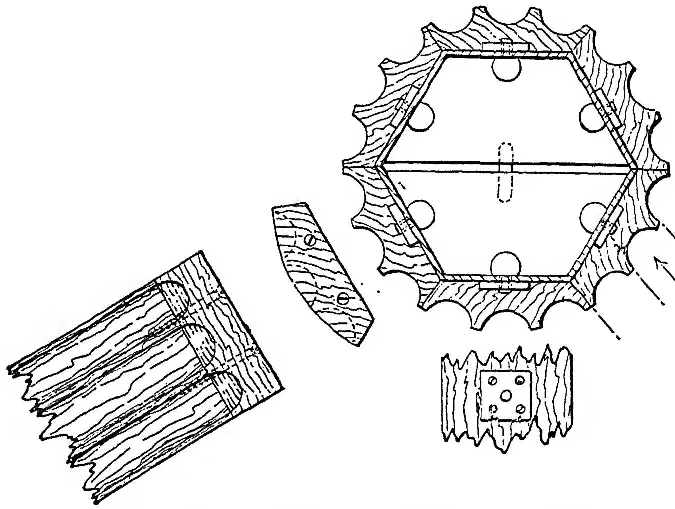


Fig. 39.—Example of Fluted Strips attached to an Iron Backing

is practicable. Usually the most convenient and the safest method of setting and securing the cores determines the choice. A very slight degree of inaccuracy in setting, or due to shifting from position in casting, will produce spoilt work. Moulds are divided horizontally, because it is easier to set cores thus than in a vertical mould of small diameter. But it is set vertically to be poured, in order to float all sullage up into the head metal, which if present on portions to be tooled would spoil the casting.

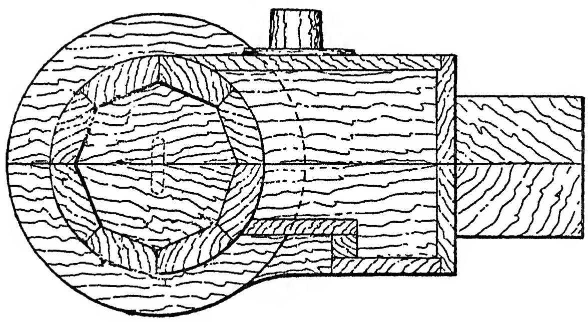


Fig. 40.—Cylinder Pattern with Steam-chest

Typical Patterns.—In the plainest cylinders the steam-chest is distinct from the main body, and a flange on the latter is provided to receive it. When practicable, the flange is always moulded downwards, because it is convenient to insert the cores for the passages in the bottom of the mould, instead of in the joint face. Prints are attached to the flange, and this is necessarily dowelled loosely to the passage block. The cylinder foot, when at right angles, is made fast to the body. But it may happen that other

dispositions of the foot may entail coring over it or jointing the pattern at right angles with the steam-chest face.

In many cases the steam-chest is cast in one piece with the cylinder body (fig. 40). Then the interior is produced with a core for which a print is attached, wide enough to afford adequate support to the core, and prints are inserted in the box for the steam and exhaust passage cores (fig. 41). The pattern portion for the steam-chest is prepared by boxing-up in order to reduce shrinkage and to economize timber.

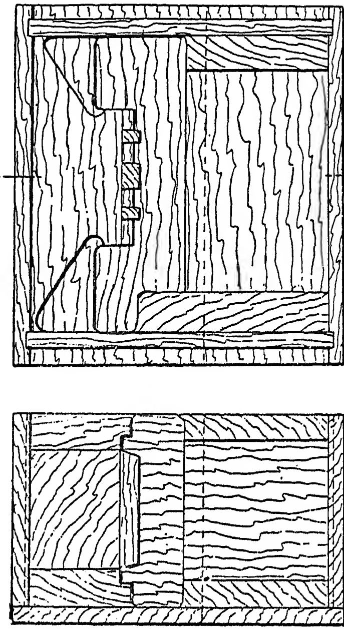


Fig. 41.—Core Box for Steam-chest Cast with Cylinder

Many cylinders are jacketed. The annular core is made in a box, complete in all details. All jacketed castings require especial care in both pattern-shop and foundry, because the metal is thin and the risks of displacement of the cores and obstruction of the vents are very great. Steam, gas, and petrol cylinders are made with jackets, and the last named are the most difficult of all, because of the large number of cores and their interdependence, and the very thin walls of metal between them, ranging from about $\frac{1}{4}$ in. to $\frac{3}{8}$ in. When two, three, or four cylinders are cast *en bloc* the separate cores may

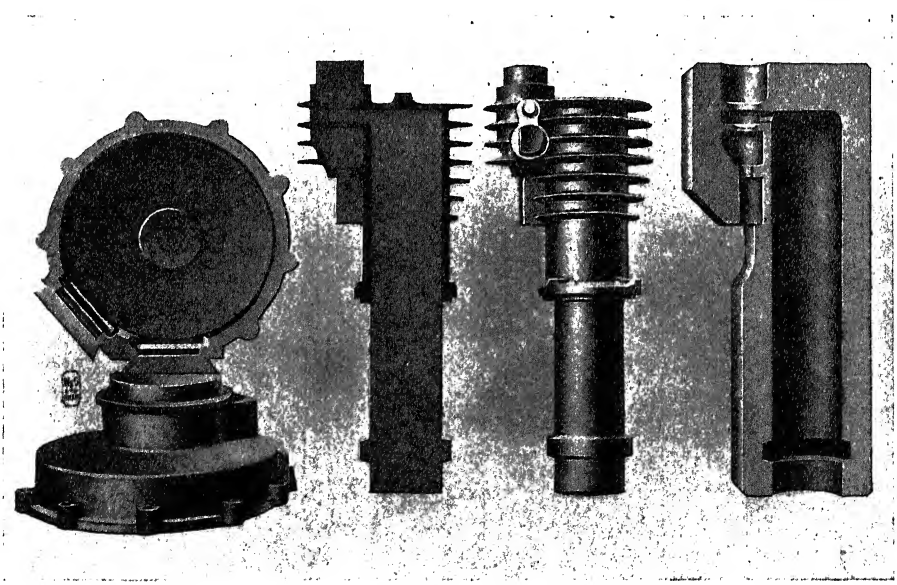


Fig. 42.—Cylinder Pattern for Motor-cycle Engine

number from twenty to thirty, depending on the design. These are almost invariably rammed in iron boxes to ensure permanence of form, and their positions in the mould are tested carefully by means of metal gauges.

Fig. 42 shows a plain cylinder pattern for a motor-cycle, by Messrs. Ernest M. Brown & Co. of Huddersfield. One-half the core box is seen at the right. The relation of the core to the pattern and its prints can be observed in the half pattern open in the joint face to the left. There the thickness of metal is painted black, a practice which is commonly adopted in cored work, since it is of assistance to the moulder when inserting the cores. A cover is seen at the left of the figure.

Fig. 43 shows the method of lagging, with other details for a small compound engine, in which the high- and low-pressure cylinders were cast together with

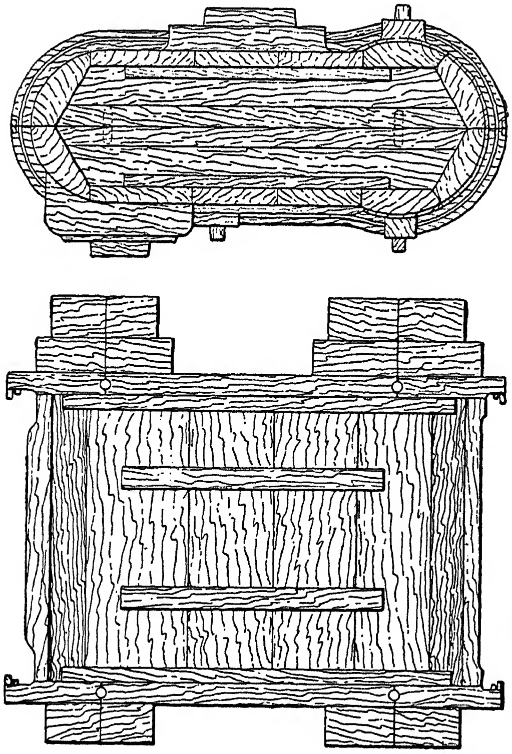


Fig. 43.—Pattern for Compound Cylinder

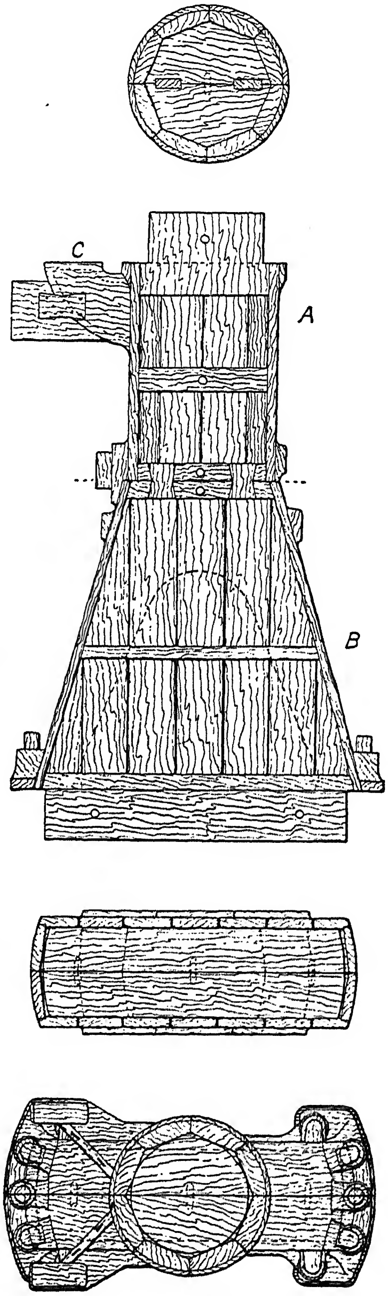


Fig. 44.—Pattern of Diesel Engine Cylinder and Base

their connecting passages. The upper view is a cross-section, the lower is one-half the pattern open in the joint face. Head metal is provided. The lags, the flat strips, the battens, bosses, and prints are obvious.

Fig. 44 gives complete views of the pattern for a Diesel engine cylinder cast in one with its A-legs. The whole of the interior is formed with cores. The upper portion A, the cylinder, is lagged and turned as a separate section, and is united to the pattern frame B with two dovetails. B is boxed-up on three cross-bars, being formed with strips having open joints. The feet are attached to this, as shown in the lowest view, which is a plan taken from the top of the cylinder, and the print is fastened to the bottom of the pattern. Two diagonal brackets are fitted loosely with skewers, and four hold-down bosses that lie below the joint of the pattern are left loose, with drop prints. A bracket C at the top is prepared separately, with the print for its lightening core, and attached to the cylinder.

2. SHEAVES, PULLEYS, AND FLY-WHEELS

The features which sheaves, pulleys, and fly-wheels possess in common are: their outlines are circular, their depths relatively shallow, and they have central arms (or discs), through the centres of which the moulds and often the patterns have to be parted. The shrinkage stresses in arms and rims cause fracture in these castings unless the pattern-maker exercises care in proportioning of parts.

Sheaves.—Patterns for these are made in wood (fig. 1) for moderate numbers of castings, in metal (fig. 45) for quantities. When wood is used the rims are built up with thin segments, the centres being made in a similar manner when they are solid-plated. Arms are locked at the centre and let into the rim, these methods being identical with those employed in the construction of toothed wheels. Patterns are divided through the centre of the arms, or these are left of the full thickness, and the upper portion of the rim is registered to the lower (figs. 1 and 45). Moulding is generally done in a three-part box, the joints being made in the planes *a*, *a* (fig. 45). But a circular grid can be used, as shown at the right hand, to carry the sand in the recess, and then a two-part box with its joint at *b* can be used. Alternatively, an annular core print can be fitted around the rim, and a series of short lengths of core laid in. This is seldom done when complete patterns are made, except in the case of cupped wheels which are provided with recesses to receive the links of chain that lie flat and edgewise alternately. But the method is of value when very large pit wheels are made with wrought-iron arms, in which case the entire rim, interior as well as exterior, is frequently formed with cores. Another form of sheave is that with a wavy gorge to

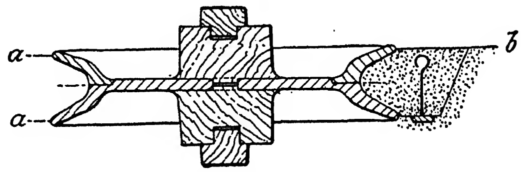


Fig. 45.—Iron Pattern for Sheave Wheel

prevent slipping of a rope, which also is provided for in a core box rather than in the pattern.

Trolley or truck wheels resemble sheaves in the fact that the presence of double flanges (fig. 2) entails the employment of a three-part box. Only the lower flange is left loose. This may be done in either of the ways shown (fig. 46). When vertical arms are fitted, either to trolley or sheave wheels, they are screwed fast in the bottom, but left loose in the top, to come up with the cope and be withdrawn therefrom.

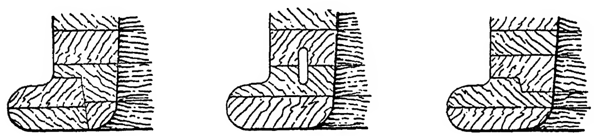


Fig. 46.—Alternative Methods of Jointing Bottom Flange of Trolley Wheel

Pulleys.—Patterns of wood are useless for pulleys. They must be of iron. And, except for repetitive work, they are not made with rim, arms, and boss in one solid piece. Each is a separate element, rim and arms in iron, and bosses in wood, from which pulleys having different widths of face, and bosses for any bores required can be made up.

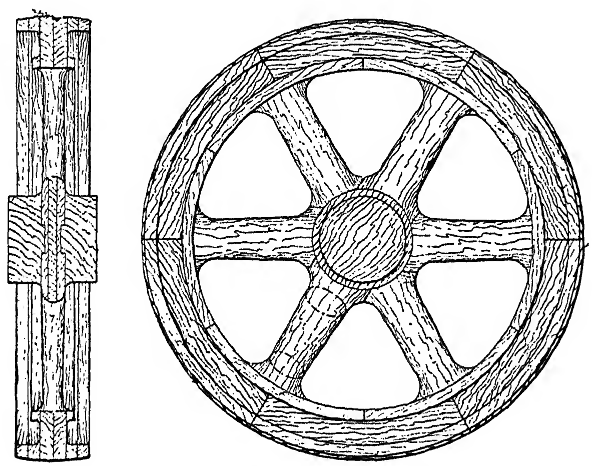


Fig. 47.—Pattern of a Fly-wheel

The system adopted is to have a large stock of pattern rims, turned inside and out, with a very slight taper and no crowning, of maximum depths likely to be required, say of 12 in. width of face in the smaller sizes and 16 in. to 18 in. in the larger. Widths narrower are produced by stopping-off in the mould. Diameters may advance by 1 in. in the first, and by 3 in. in the second. When the volume of trade is large, one series of light pattern rims and one of heavy is stocked. The arms are made of cast iron to fit easily within the rims. These also are made light, having only the elliptical section, and heavy with shallow vertical ribbings. The bosses of wood fit to any of the arms with a standard size of stud in a centre hole, say $1\frac{1}{2}$ in. diameter.

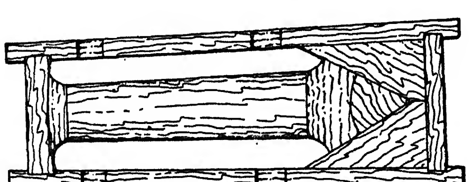


Fig. 48.—Core Box for Fly-wheel Arms

From these elements the moulder produces pulleys of any widths of

face by stopping-off, and centring the arms with a gauge, and, if required, pulleys of wider faces than the rims by "drawing". Double-armed castings are made from the same sets. From the same pattern parts, castings are "split" in halves by the insertion of lugs and prints to receive the splitting plates.

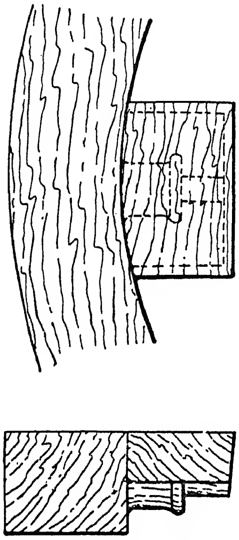


Fig. 49.—Segmental Piece for Rim of Fly-wheel

Fly-wheels.—The rims of these (fig. 47) are built up with segments, and the arms, locked about the centre, are sunk into the rim during the course of building-up. Bosses are studded at the centre. Patterns of wood are suitable, except for highly repetitive orders, for which metal is substituted, in which case the work is machine-moulded. All fly-wheels, except those of small diameter, have arms. These may be straight, but are preferably curved to accommodate shrinkage movements. The smaller wheels have single curves, the larger generally double. But solid-cast arms are not safe for the larger wheels, which are either provided with those of wrought iron, or the arms and rim are cast in separate pieces and bolted or cottered together. When large wheels are cast with arms intact, these are made in cores, for which the pattern-maker provides a box, and also sweeping boards to form the rim.

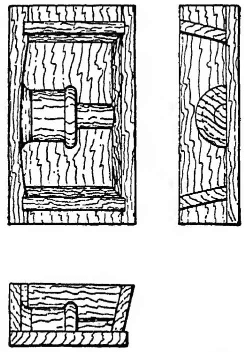


Fig. 50.—Core Box for Fly-wheel, half boss

When a wheel has cast-iron arms, the form of core box used is shown in fig. 48. The arm piece is one-half the thickness of the arm section, so that two cores are jointed to include the mould for the complete arm. The box is shown as for a six-armed wheel, the jointing angle at the centre which contains the boss section being therefore 60°. The outer radius is that of the interior of the rim. The notches, cut in the edges of the box frame, receive the grid which sustains the core. Rims of any section can be produced with sweeping boards and sectional ramming blocks.

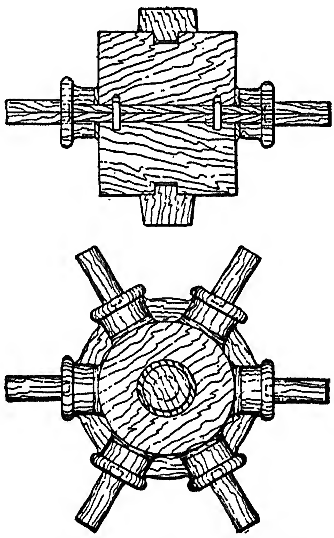


Fig. 51.—Pattern Boss for Fly-wheel

When wheels have wrought-iron arms, these are cast into bosses in rim and central boss. Obviously down-jointing cannot be done, and therefore the upper halves of the rim bosses and their

prints must be cored over, and the mould and cores be covered with a plain top. Fig. 49 shows the provision made for the rim. A short length of sweep has a half-arm boss with its half print, covered with a block print. Into the impression made by this the core, rammed in the box (fig. 50), is set. Taper is given, as shown, to the sides of print and core. The central boss that corresponds with this type of wheel is shown in fig. 51. This is rammed in a parted box distinct from the rim, having the joints separated for the insertion of the arms, and is dried. The boss mould is centred relatively to the rim, and levelled before the arms are inserted. These are then covered with the top half of the boss mould.

3. GEAR-WHEEL PATTERNS

Although this department of work has been deeply invaded by the insistent demand for cut gears, a very large volume remains. Wheels with cut teeth are expensive, and they are not usually found in common machines, such as ordinary cranes, contractors' machinery, and the like. Another important fact which favours the retention of cast gears is that the patterns now made are far superior to those of some years ago. A high grade of workmanship has been demanded and met, partly due to the employment of machines for cutting pattern teeth, and partly to the fact that firms make these for the trade, the pioneers being Messrs. Ernest M. Brown & Co. of Huddersfield. And Wadkin & Co. of Leicester have revolutionized the methods of some shops by the introduction of the "Mechanical Wood-worker" in core-box work, and in the teeth of gear-wheel patterns. In the general shops these patterns are the speciality of one or two only of the hands.

Tooth Forms.—It is essential that the teeth of all wheels of the same pitch shall be made to a correct contour, so as to secure a rolling contact as far as may be and a uniform velocity-ratio. In cycloidal or double-curved teeth this is secured by making the diameter of the rolling circle, to be rolled on the pitch circle, equal to the radius of the smallest wheel of the series. This gives radial flanks for the smallest or basic pinion, and undercut flanks for those below that size. This is embodied in an odontograph scale.

For involute or single-curved teeth, which have been largely substituted for cycloidal, the basis is the rack, having teeth with straight, sloping flanks. The point of contact of the teeth lies on the line passing through the point of contact of the pitch circles and tangential to the base circles. In the cycloids, curves are generated from the pitch circle; in the involutes, the pitch circles have but an arbitrary relation to the base circles. This explains why correct tooth contact occurs whether the ideal pitch cylinders are or are not in contact, and why, by increasing the addendum in small pinions, undercut of the teeth can be avoided. The circular pitch is most generally used for pattern gears, but the diametral is commonly associated with the involutes.

Tooth lengths are proportioned to pitches, but teeth are always made shorter now than they were formerly. Proportions are given in many textbooks, and they are standardized in the shops.

Spur Wheels, Pattern Construction.—For these, two materials are used chiefly: yellow pine and Honduras mahogany, or Baywood, the first for the bodies, and the second for the teeth. Yellow pine is suitable for teeth when only moderate numbers of moulds have to be taken.

Only very small pinion patterns are made solid, that is, with the teeth in one with the centre body, and the grain running longitudinally. Pinions of over 6 in. or 7 in. diameter must have their centres built up. In the smaller sizes, courses of sectors are glued up, the grain running radially. In those above say 8 in. or 9 in., segments are used, the grain running tangentially. Thicknesses will range from $\frac{1}{2}$ in. to 1 in. in small and large patterns respectively. Gluing is done carefully, and nails or wooden pegs reinforce the joints against the rough usage of the foundry. The rims are turned and finished before the teeth are taken in hand, these being always made distinct from the rim to get longitudinal grain.

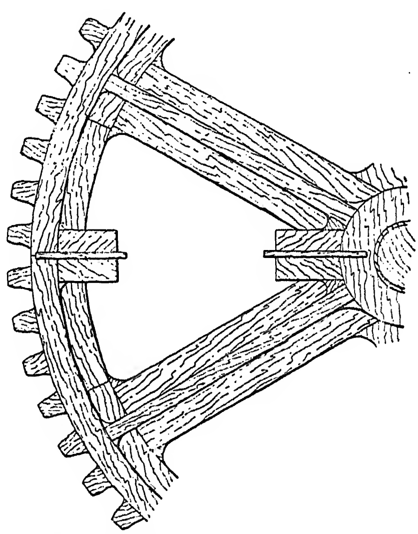


Fig. 52.—Portion of Pattern Wheel with Splitting Lugs

Methods of Constructing Wheels.—The larger pinions, and smaller wheels, have solid-plated centres, built into the rims. All large wheels have arms made separately from the rims, which are built up. Plated centres are built up with sectors having the grain radiating, in not less than two thicknesses. Or narrow strips with open joints are prepared, and the courses of rim segments are glued up on the discoid centres. Rims for armed wheels are built up and turned as separate elements into which the finished arms, usually of T-section, are fitted. When they have the section of a + they are built into the rim at the half-way stage of the courses of segments. During the fitting, care must be taken not to drive them into their recesses so tightly as to distort the rim. Only light hand pressure is employed, with glue and fine screws. Though the locking together of the arms at the centre is rather flimsy, the screwing on of the central boss and the fitting of the vertical arms provide additional strength. The latter abut against the boss, or fit in shallow grooves cut in it. They also abut against the rim. Fillets or " hollows " glued in all angles further stiffen the structure. With arms of +-section, the ribs that come in the top should be dowelled loosely with that boss portion, for reasons previously stated Fig. 52 shows a wheel pattern with split lugs.

Tooth Formation and Fitting.—Teeth are either shaped first and attached to the rim afterwards, or they are worked in their places.

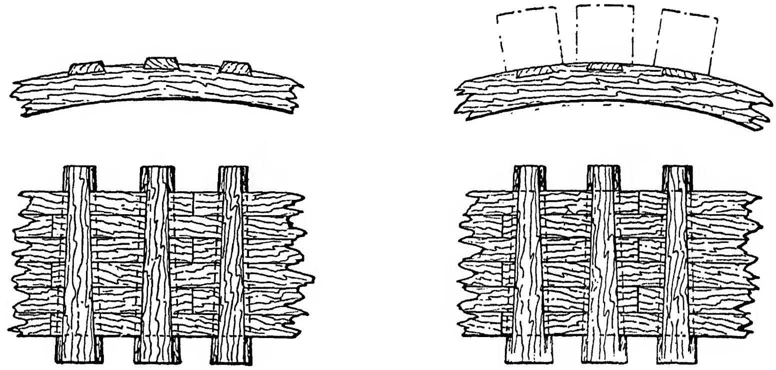


Fig. 53.—Method of Fitting Teeth with Dovetails

The latter is to be preferred when a dividing-machine and a fly-cutter can be used. But if not, the best way is to fit each tooth with a dovetail (fig. 53). Turn, pitch, and mark the teeth out in place, remove them to be shaped with planes, return and glue them permanently. The best pattern wheels, apart from those machine-made, are constructed in this way.

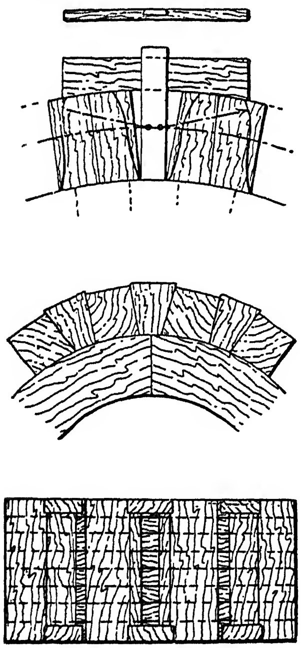


Fig. 54.—Method of Fitting Teeth to be Shaped in Position

Other methods are, to plane each tooth separately, fit and glue it to the rim, or to glue rough blocks on the rim, turn, pitch, and mark out (fig. 54), and cut the shapes through with chisel and gouge. These methods are however not entirely satisfactory.

Using a fly-cutter, the rim is turned $\frac{1}{8}$ in. or $\frac{3}{16}$ in. below the roots, and rough blocks, each wide enough to include three or four teeth, are glued on in contact. Material is thus left below the roots on which the radius or fillet is cut without leaving a "feather edge". The blocks being turned, the tooth spaces are shaped in a machine, which also divides for pitch. No taper is given, and since the teeth are accurate, they can be drawn through a stripping plate, in hand-made moulds, or on a machine.

The chief advantage of planing the teeth previously to attaching them to the rim is that they can be shaped accurately. They are planed in a box made of hard-wood, having the cross-section of a tooth. The difficulty lies in gluing the teeth to the rim. Setting is done by centre lines, or by the edges of the flanks, to lines pitched and scribed around the rim. Errors in pitching and in getting

out of square arise. The first is checked with calipers as the work proceeds before the glue has hardened, the second with a set-square tried along a flank and working from a straight-edge.

To glue rough blocks on and work them in place with gouge and chisel requires great care to get straight flanks. Using a small straight-edge, and carefully glass-papering, the method is reasonably accurate, though tedious.

Since rough blocks, glued or dovetailed, have interspaces, these may be filled in with wedge-shaped bits (fig. 54) to afford a continuous surface. It is convenient for the turning, but not essential, since if light cuts are taken with a sharp gouge, the teeth will not be knocked off nor the grain split. And although a continuous surface is useful for locating tooth curves on, the centres may equally well be set on a zinc templet piece as shown in the upper part of fig. 54, worked round the periphery.

Tooth centres are pitched round on one side, and squared over to the side opposite. The tooth thicknesses are set to right and left of the pitch points, and the curves starting from these are described.

Bevel Wheels.—These are based on precisely the same principles and elements as the spurs, in regard to the shapes and proportions of the teeth. But the pitch and related dimensions are always taken on the major diameter, those on the smaller diameter being controlled by the width of face of the teeth. The teeth are not developed on the real diameters, but on conical surfaces at right angles with the pitch cone (fig. 55).

Bevel gears are marked out as shown by fig. 55. The pitch cones *ab* are the primitive rolling surfaces. The diameters A, B are the real diameters for the actual pitches. Through *a*, the point of intersection of these, a line is drawn perpendicular to *ba*, meeting the axes of the primitive cones in *c* and *d*. Circles described with radii *ca* and *da* are the pitch circles on which the teeth are drawn. In other words, they correspond with the curves of spur gears of radii *ca*, *da*. As the teeth taper from the major diameter to the apices of the cones, the tooth curves on the minor diameters are obtained on the developed surfaces having radii *fe*, *ge*. The tooth forms for both are shown to the left, and those for the minor radii are repeated at the right.

Pattern rims are built up with courses of segments that overlap sufficiently (fig. 56) to include the cone section. Two chuckings are essential; whether the back or the front is done first does not matter, since a straight-edge is laid across the rim and each is turned with the aid of templets. Nails cannot be used so conveniently to reinforce the glued joints as wooden pegs, though the risk of segments starting after the teeth are attached is nearly negligible.

Teeth are fitted and worked in either of the ways described in connection with spur gears. If fly-cutters are used, they are not selected for either diameter, but for a location at about a third of the tooth length from the major diameter, and two settings of a flank are needed.

Worm Wheels.—These are made much less frequently by the pattern-maker than formerly, since the practice of generating has grown in favour,

with the employment of double- and treble-threaded worms. For ordinary service, cast gears with single-threaded worms are still used, and are less costly than those produced by hobbing.

Worm gears have the helix for their basis, though this is somewhat disguised in the case of the wheel. The worm is a continuous thread of ex-

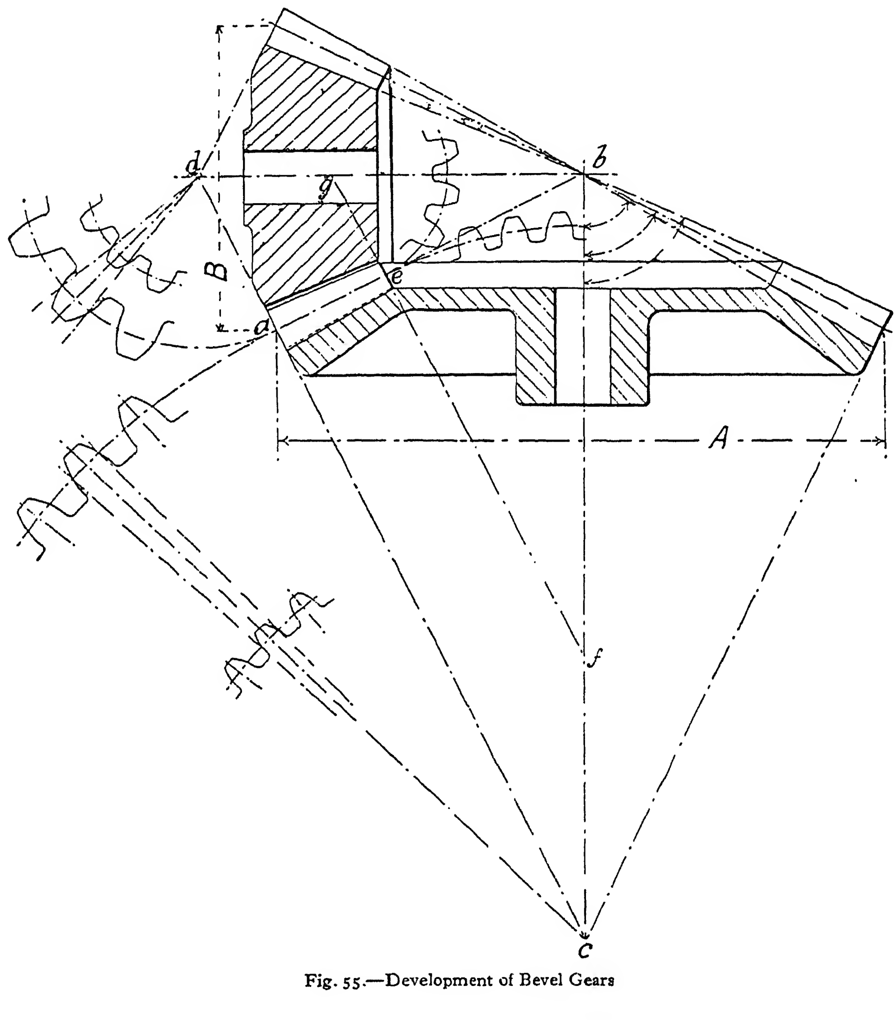


Fig. 55.—Development of Bevel Gears

tremely short axial pitch or lead. The wheel which it drives has a number of short helical teeth of extremely long axial pitch. The axial pitch of the worm, if single-threaded, measures the same as the circular pitch of the wheel teeth. The wheel may contain any number of teeth. The worm diameter is usually from twice to three times the pitch. The curvature therefore being small, the teeth of the wheel should form envelopes of the worm thread to ensure durability and smooth movement.

The section of the worm thread is that of the involute rack. A worm

pattern can be constructed in wood, divided longitudinally, but this is not a very satisfactory method. If a cast worm is used, the pattern should be cut in metal and moulded vertically, screwing it out of the mould through a stripping plate, and relieving its weight with a counter-balance suspended from a rope passing over a pulley. But it is better to cut worms in the machine-shop, in which case the pattern-maker can employ the actual worm as a perfect guide by which to shape the teeth of the wheel.

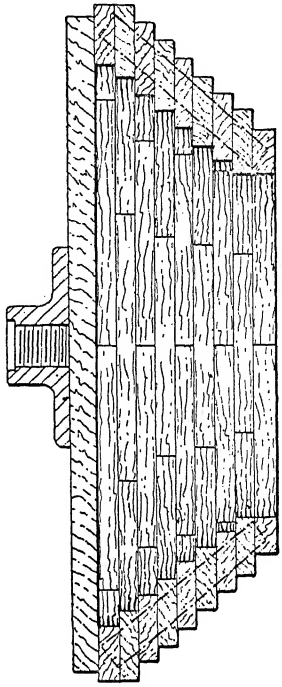


Fig. 56 —Rim for Bevel Wheel

Pattern wheels must be jointed along the middle plane, either through the central plate, or leaving this in one piece, undivided, the half depth of rim is registered to it, as in the case of sheave wheels. Segments are built up, overlapping, and the concavity for the tooth blocks is turned with a templet, the interior of the rim being similarly dealt with. Blocks for the teeth are fitted and glued to each half-rim, and the abutting ends that come in the joint face are turned at separate chuckings of each half-pattern, and at the same time the curves are imparted to the points with the aid of a templet working from the joint face. The outer ends of the teeth are then finished.

The teeth are pitched and their thicknesses and shapes marked in the

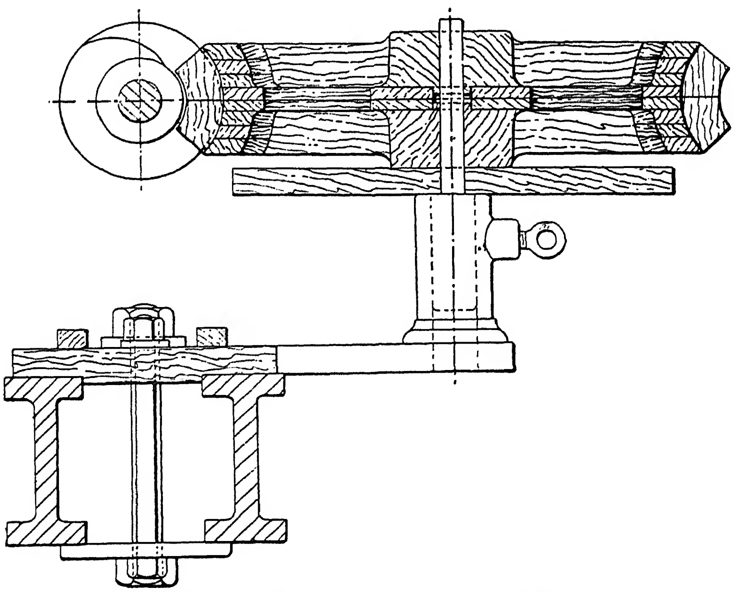


Fig. 57.—Worm-wheel Pattern mounted for Cutting the Teeth

central joint plane of the pattern precisely as for an involute spur wheel. The tooth sections change constantly from the centre to the outer ends.

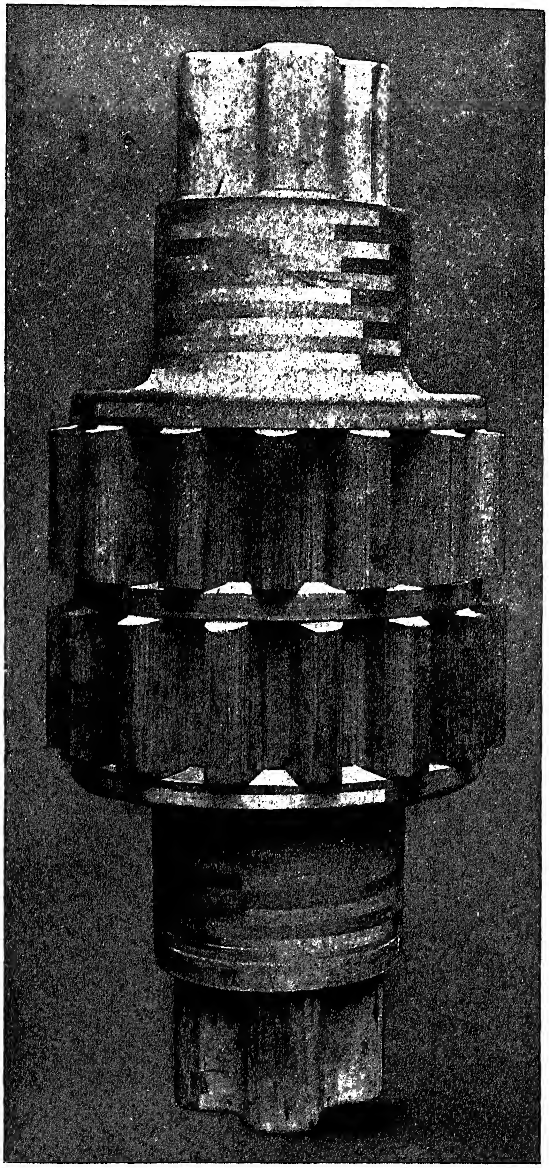


Fig. 58.—Rolling-mill Pinion, 15 teeth, 7-in. pitch, 26-in. face

The larger the angle or slope of the teeth, as in worms of small diameters and those with multiple threads, the more marked are the changes in section. Here the advantage of employing the worm as a templet guide for cutting the wheel teeth is apparent. The worm is set between lathe-centres, and the wheel is mounted on a stem in the T-rest. The wheel and the worm are moved into contact (fig. 57). The application of chalk or of red lead to the worm indicates, by its transference to the wheel teeth, the high parts from which material must be removed.

If the wheel contains a large number of teeth, the work of cutting may be hastened by shaping, say, half a dozen correctly from worm contact, and then marking the shapes of the other ends so obtained on the remaining teeth. These can then be roughed out rapidly with gouge and chisel, leaving the finish to be imparted by the assistance of worm contact.

A massive spur pinion pattern, which stands higher than a tall man, is shown in fig. 58. The teeth are shrouded to the pitch circles. There is a joint in the pattern along the face of each shroud. These are built up with segments, as are also the bosses. Fig. 59 shows a segmental pattern, from which large toothed rings are built up, being bolted together by the end

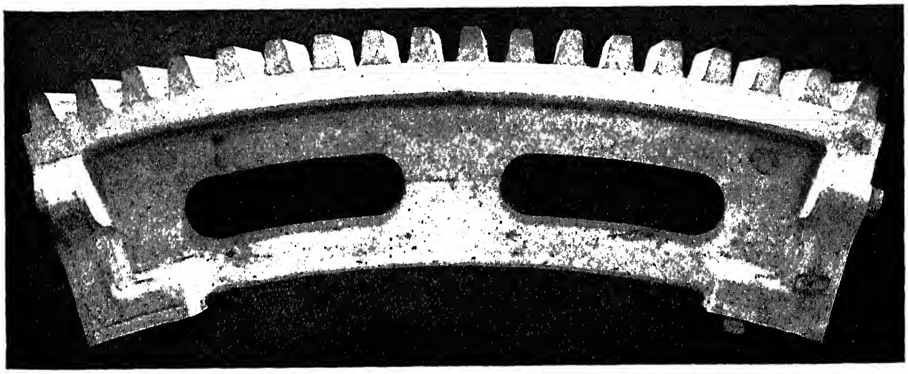


Fig. 59.—A Segmental Pattern for building up a Toothed Ring

flanges, for use on revolving cranes, turntables, and swing bridges. These are by Messrs. Ernest M. Brown & Co. of Huddersfield.

4. MACHINE-MADE WHEELS

The economies of this kind of work are associated chiefly with the larger gears, and for those casual orders when only two or three castings are required, for which the cost of complete patterns would be prohibitive.

The employment of a few teeth from which to mould an entire wheel rim, and of a core box to include the arms, had been practised long before the wheel-moulding machines were invented. Teeth attached to a segment are worked round, and rammed in successive stages, at the end of a radius bar centred on a pin (fig. 60). Another

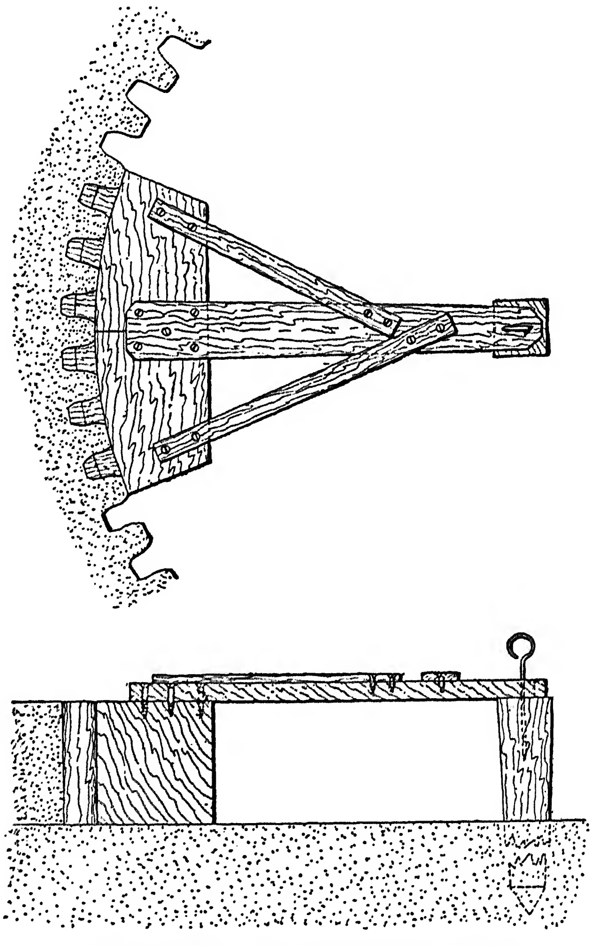


Fig. 60.—Segmental Block moulding a Spur Wheel

method is that of ramming a few teeth in a core box, and laying the cores round a circle. The wheel machine includes a dividing apparatus with change gears for all pitches, and mechanical slides for withdrawing the segmental blocks that carry two, three, or more teeth. Two designs of machines are made, one having a moulding table on which the smaller gears are moulded in top and bottom boxes, the other having the mechanism carried on a column sunk in the floor, in the sand of which the teeth are moulded, to be covered with a plain top box.

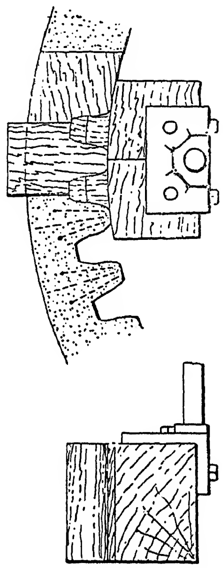


Fig. 61.—Tooth Block in Mould

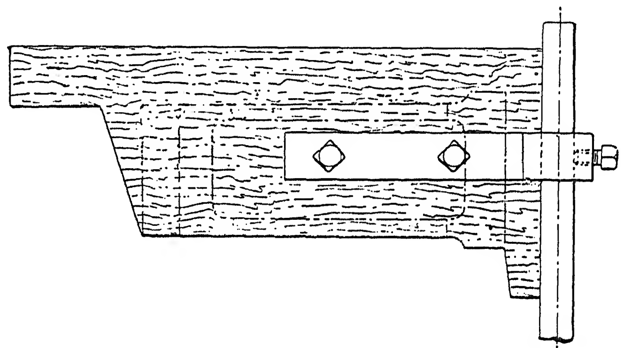


Fig. 62.—Sweeping Board for a Spur Wheel

The Pattern Parts.—The essentials, varied in details with the class of gear and the sections and outlines of arms, &c., are the tooth block, the sweeping boards, and the core box.

Tooth Blocks.—A tooth block is like part of a wheel rim having a few teeth cut on it, attached to a backing of suitable shape and dimensions, and screwed to the tooth carrier of a machine. The simplest blocks are those for spur (fig. 61) and bevel gears, which are withdrawn vertically. Those for helical, double helical, and worm wheels are withdrawn in the horizontal direction, except in those machines which do not include this provision. For use in these, the pattern-maker divides the block, separating the main backing from the actual teeth, which are carried on a thin backing, and dovetailed loosely to the portion that is attached to the carrier. The latter is first lifted vertically by the machine, followed by the teeth, taken away horizontally with the fingers.

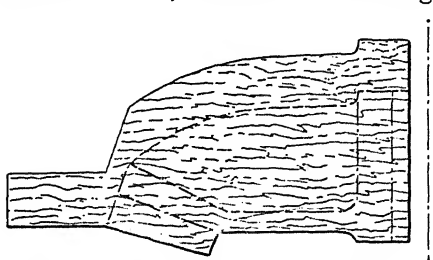


Fig. 63.—Sweeping Board for a Bevel Wheel

Sweeping Boards.—These (fig. 62) are necessary to form a bed to receive the cores, to make the joint faces at their correct heights between drag and cope, to indicate the radii of the teeth, and, in the case of bevel

wheels, to correspond with the tooth points. These vary in details with the shapes of wheels. A plane top is general for spurs, but the top for a bevel wheel is curved to follow the edges of the vertical arms (fig. 63). The edges for sweeping the bottom and top moulds are usually cut on the same board which is reversed on the bar. The latter is of a standard size (fig. 62), so that all boards are shorter than the real radius of the wheel by the radius of the bar, to which they are attached with an iron strap. The radius of the tooth block, though set by the bed swept, is checked, and, if necessary, finely corrected with a strip that gives the exact distance from the central bar to the point or the root of a tooth.

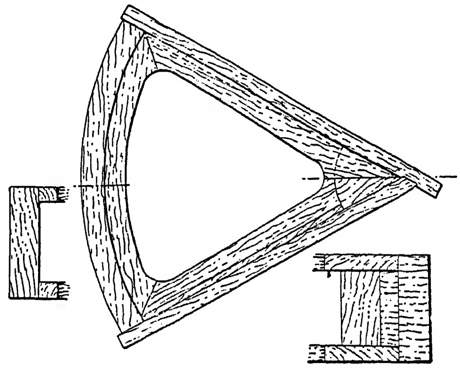


Fig. 64.—Core Box for Wheel Arms of H-section

Core Boxes.—Arms of all shapes can be made with cores, but the most convenient are those of H-section, and these therefore are most common (fig. 64). Bevel wheels have arms of T-section. Cores are rammed, dried, blackened, and set in the mould on the swept bed without aid from prints. The spaces between the cores corresponding with thicknesses of metal are set with wooden gauges. Their own weight and the pressure of the cope when the mould is closed prevents them from shifting. Central bosses and prints are swept, or bedded-in.

5. BEDS AND ALLIED FORMS

These being the bases for engines, pumps, machine-tools, cranes, &c., occur in an immense variety of outlines and dimensions. Only broad principles can be stated here.

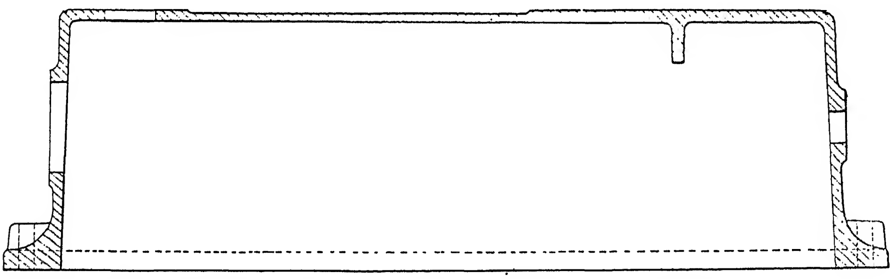


Fig. 65.—An Engine Bed suitable for Self-delivery—the top face being lowermost in the mould

Method of Moulding.—This is the first thing to be determined. Usually the top face of the bedplate pattern goes to the bottom of the mould. This ensures that sound metal shall be present in those surfaces which

have to be machined later. The question of moulding by bedding-in or turning-over is settled by the numbers of castings required and the

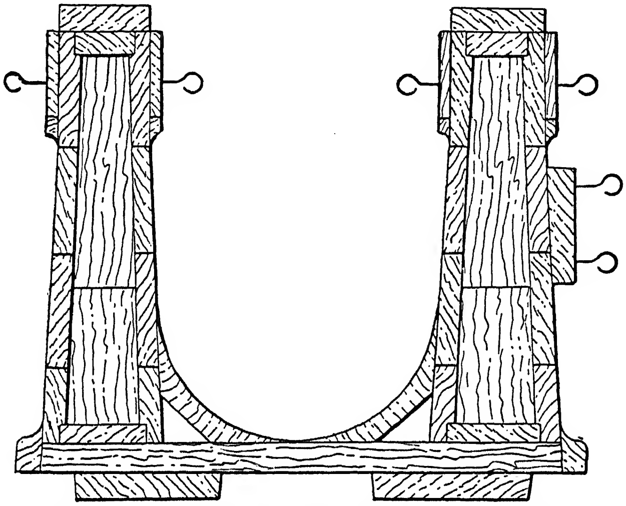


Fig. 66.—Section through Crank-shaft Bearings of Engine Bed. Pattern shows boxing-up, prints for cores, and loose pieces

boxes available. The latter method is preferable, except for beds of the largest dimensions. The choice of self-delivery, or of coring the interior, depends chiefly on the bed section, and on the relative proportions of width to depth of interiors. As there is no objection to giving plenty of taper, a good slope is always given to the outside, and as the thickness of metal is equal throughout, the internal taper favours delivery (fig. 65). Many deep beds therefore with wide internal spaces deliver themselves, the interior "green sand core" being carried on a grid suspended from the stays of the top box, or, if special boxes are made, the stays are brought down inside to a distance of about $\frac{3}{4}$ in. from the pattern all round. But this method is not practicable when beds are narrow and deep. In these cases, the interior is taken out with cores inserted in print impressions (fig. 66). This is very convenient when loose pieces have to be attached to the outsides, as these can be withdrawn laterally through the open interior.

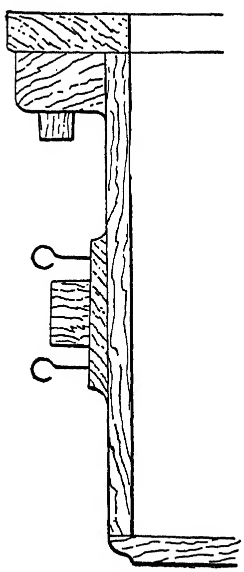


Fig. 67.—Shows Loose Boss and Print on end of Engine Bed.

There are few patterns which do not carry some loose pieces, and core prints for the insertion of small cores (figs. 66 and 67), for bearings, and recessed portions in varied forms. In some cases it is convenient to carry all the outer mould on an encircling plate for the purpose of getting at recessed

portions for cleaning and coring. Many beds of large dimensions are made without full patterns from motives of economy. The exterior mould is

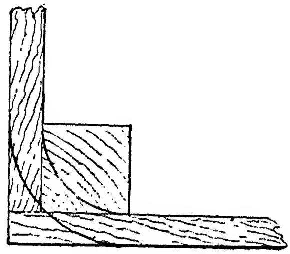


Fig. 68.—Formation of Curved Corner

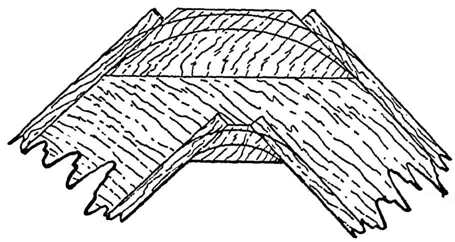


Fig. 69.—Method of making a Curved Corner

made from a skeleton frame, aided with strickles or sweeping boards, and cores impart the shapes to the interior portions. In all long and narrow beds, solid-plated on one face only, the effect of unequal shrinkage is to

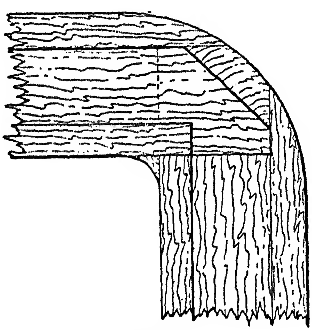


Fig. 70

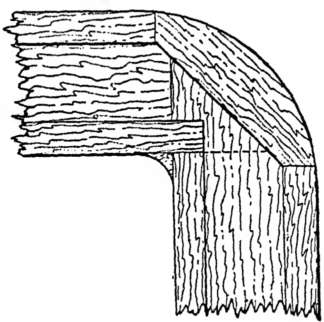


Fig. 71

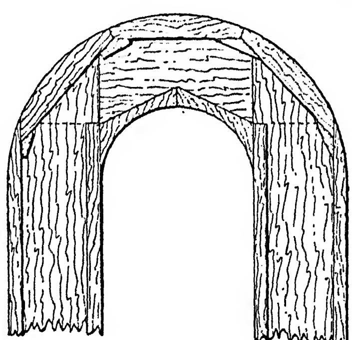


Fig. 72

Methods of Blocking adopted for Curves

cause curving or camber, the solid-plated portion when cold becoming concave lengthwise to the extent of from $\frac{1}{4}$ in. to $\frac{1}{2}$ in., depending on the length. The pattern must be curved in the opposite direction to neutralize this effect.

Methods of Union.—The union of corners and the formation of curved ends are shown in figs. 68 to 72. In fig. 68 sides and ends abut at right angles, and a square block is glued in, which when set is worked to interior and outside curves. In fig. 69 a similar method is employed for interior and exterior radii, all being connected with a plated covering, after the inner as well as the outer curves have been cut, the interior being for self-delivery, as is the previous figure.

The next group represents portions of patterns, the interiors of which have to be cored. This permits of making stiffer constructions. The thicknesses of stuff are greater, and screws can be used if thought desirable to assist the glue. Figs. 70 and 71 are alternative methods for the outside curves. Both are strong, and are reinforced with the screws that secure the plated portions, halved at the corners, to the verticals. Fig. 72 is a semicircular end, made in the strongest way. Risk of shrinkage is reduced by making the segmental blocks short, and they are reinforced with the strips glued in the angles. The inside curve is made of two pieces having the grain running perpendicularly, in order to avoid short grain at the ends. The plate is made with strips having half-lap joints, and is screwed to the sides. This method is suitable for the semicircular ends of beds and of other patterns of that type.

6. SCREWS

This work includes the production of helices in pile screws, conveyors for elevators, worms, and propeller blades, cut in wood or swept up. The patterns for these contain one or more than one revolution, or a fractional portion of a revolution. Although made in different ways, the principle involved in all is the same, viz. the development of a helix is an inclined plane, or conversely a helix may be imagined to be an inclined plane wound round a cylinder. This is translated into actual practice in many small patterns by cutting an inclined plane in paper and wrapping it round a cylinder as a guide for working by. One templet of this kind may be used for the base of the screw, the other for its tip. The pitch is alike in each, but the lengths of the envelopes and the angles of the helices differ. The pitch is the distance between the centres of a helix or blade when it has made one revolution. The diameter is measured across the tips of the blade.

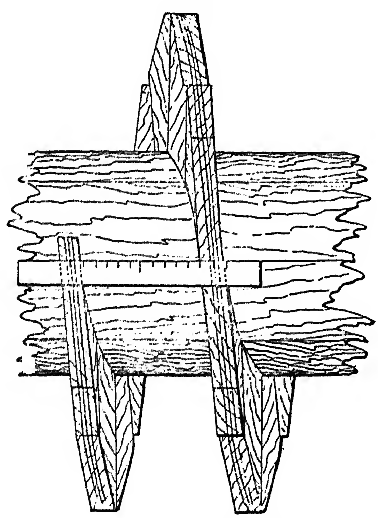


Fig. 73.—Marking the Tip of a Pile Screw

Pattern Construction.—In pile and conveyor screws (figs. 73–75), and in worms, which are members of the same family, the blades or

threads would suffer from very short grain if they were cut in one solid with the cylindrical body. This therefore is prepared first, being jointed along the centre and dowelled. The blade is fitted in short segmental divisions and glued permanently into shallow grooves cut around the body, but if the blades are deep they must be screwed temporarily, to be withdrawn from the mould after the delivery of the cylindrical body.

It is generally convenient to mark the width of the grooves on the templet

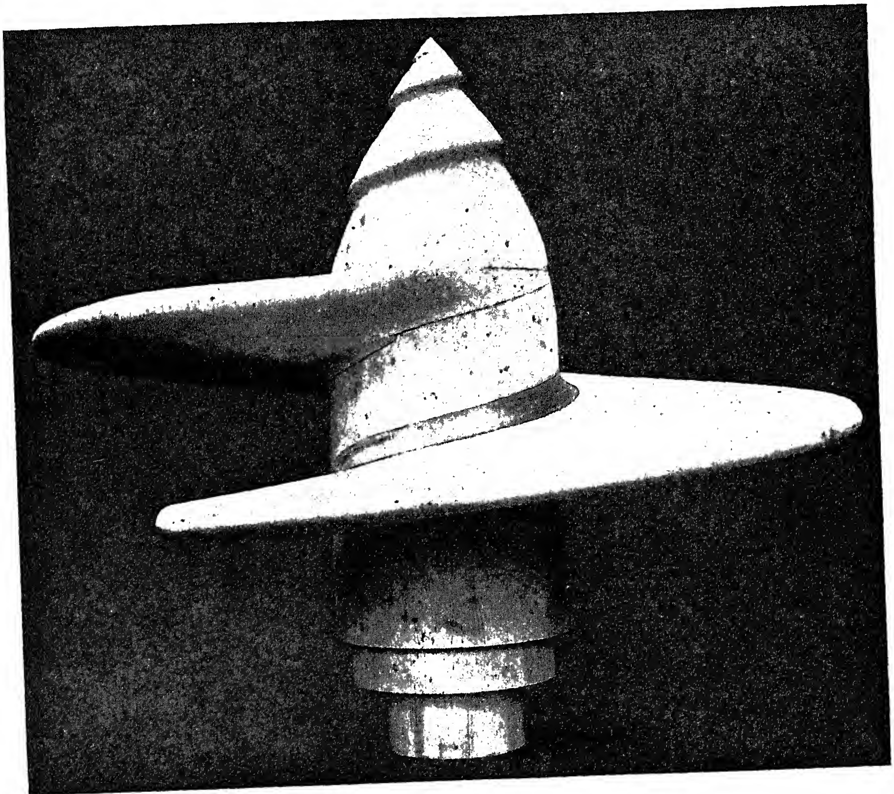


Fig. 74.—A Pile Screw

sheet of paper, through which they are cut on the turned body. The length of the pitch and of the circumference at radius *r* form a rectangle, whose diagonal is the development of the helix at radius *r*. Another line is drawn parallel with this to represent the width of the groove to be cut in the cylinder. If there is more than one turn of the helix, the construction is repeated. The paper when glued round is an accurate guide to the workman who cuts the spiral groove with saw, chisel, and router. The segmental blades are fitted into this, prevented from overlapping by the insertion of a flat dowell next the outer edges, and secured with screws put in from the joint faces, for which the pattern has to be removed from the lathe, and taken apart.

Although this method is convenient when a continuous cylinder affords a good basis for the paper, it is not practicable for the tips of the blades, since the helix is not cut in solid stuff. Then the method of intersecting lines is adopted. Here the circumference and the pitch are divided into the same number of equal parts; the larger the number the more nearly accurate will be the results. A diagonal drawn through successive intersections will delineate the screw thread (fig. 73). A line drawn parallel with this is required for the thickness of the blade at the tip. As there is a gap between the threads, the divisions are marked on a slip of wood. The

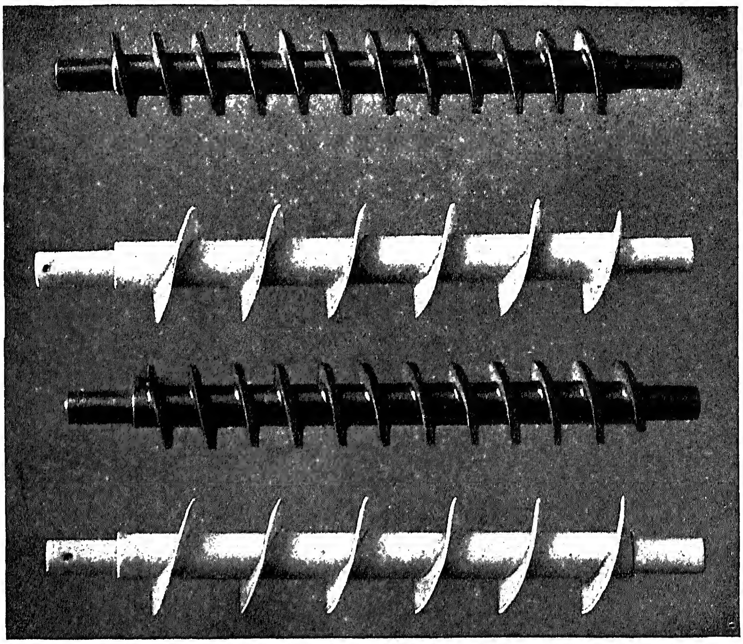


Fig. 75.—A Group of Conveyor Screws

divisions are scribed off on the pattern revolved in the lathe. The blades have to be removed to be worked. This is done with a narrow plane, slightly convex on the face. Radially, every portion of the surface from centre to circumference must be straight.

Propeller blades are short sections of multiple screws, two, three, or four in number. When pattern blades are made for these, in the smaller sizes, the boss is included, and the blade is glued up with strips that overlap at the edges to embrace the screw formation, worked through with planes. The method of intersecting lines is adopted.

Screws produced with Templets.—Large propellers are swept up in loam by the aid of sheet-iron templets having the upper edge cut to the inclined plane that corresponds with the slope of the face of the blades. As many templets are cut as there are blades. These are set round in a circle,

d their upper edges guide the movements of a sweeping board which proces the shape of the loam beds on which the strips, that correspond with e changing sectional shapes of the blades, are laid. This work is repeated many times as there are blades, the templets being set equidistant round e circle.

Screw Drums.—These, grooved spirally to receive the wire ropes the chains used on large cranes, are seldom cut in wood, because the pense is too great. They are sometimes cored, but a cheaper and more

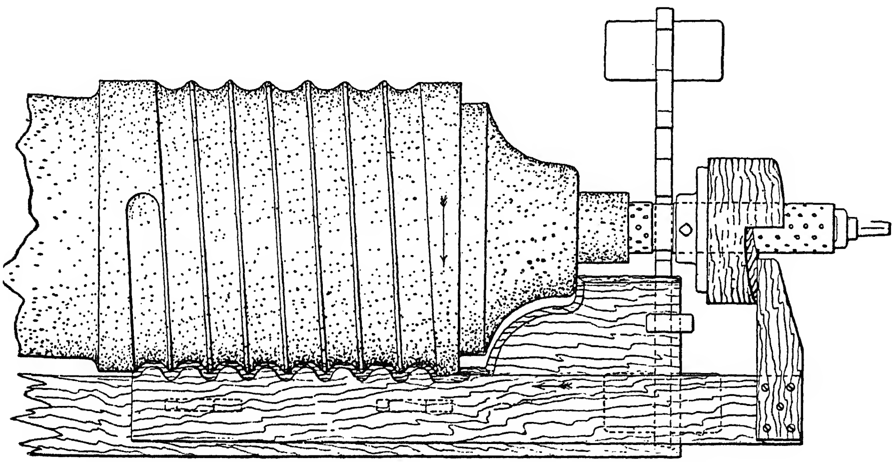


Fig. 76.—The Use of a Templet Screw to control the Striking Board for the Loam Pattern of a Spiral Crane Drum

curate method is to sweep them in loam. Drums up to about 3 ft. 6 in. diameter are swept as loam patterns to be moulded. Those over that ze are made as loam moulds with the axis of rotation set vertically. In ch case the pitch of the screw-thread is reproduced from a templet which ntrols the longitudinal (fig. 76) or the vertical movement of the sweeping oard. The templet is cut by the guidance afforded by inclined planes arked on paper and glued within and without. The grooved sections are it on the edge of the sweeping board. Since this is moved through a disnce of one pitch during one revolution, the result is a true screw in loam. space equal to the thickness of the board has to be filled up and made ood by hand, because the board has to be moved back to its starting position veral times before a smooth loam surface can be completed.

7. PLATED PATTERNS

The practice of attaching patterns to plates has grown enormously in consequence of the immense developments of machine-moulding. But it ante-dated this, and is in extensive use apart from the aids afforded by machines. It is derived from and is an extension of the employment of joint or bottom boards.

Bottom Boards.—The bottom or joint boards, which are stocked in many sizes in foundries, are made of thick, narrow strips with open joints united with battens. They have holes bored to receive the pins of the bottom parts of moulding-boxes, and are of general utility, since any patterns that will go in a box can be rammed on the bottom board. Two results are achieved, one being that the ramming of a dummy mould, for the sole purpose of getting a joint face, is avoided; the other that the board affords a level bed for the pattern, so avoiding risk of its winding during ramming.

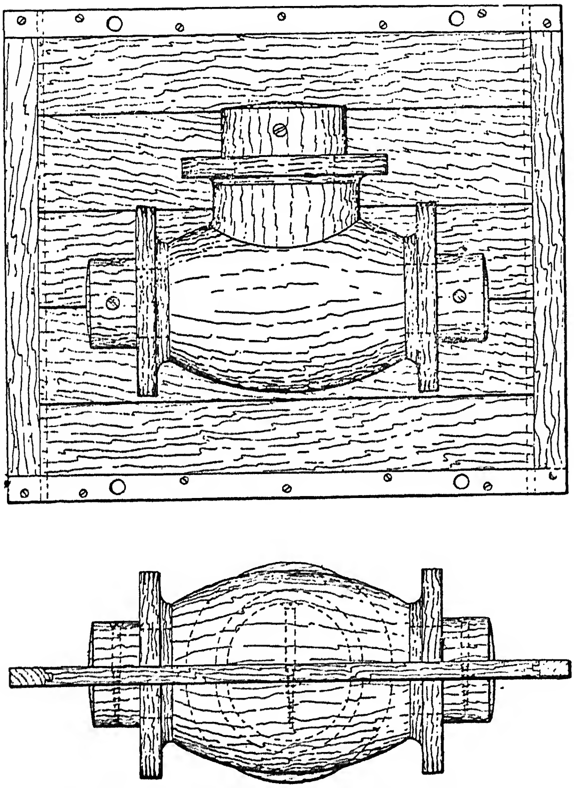


Fig. 77.—Wooden Cock Pattern mounted on a Joint Board

Permanent Plates.—At an early stage, when work becomes repetitive, an obvious economy is secured by attaching patterns to boards, and making these and the fitted boxes a permanent working unit. But then only the bottom box can be rammed on the board; the cope must still be rammed on the joint face of the bottom box, turned over to receive it. The next stage therefore is to attach the two portions of a pattern to a single board (fig. 77), without battens, and to fasten both box parts together with the pins passing through holes in the board. Here, though turning over is necessary, the advantage remains that both joint faces are provided by the board, and that both halves of the pattern are prevented from bending or winding. A more advanced stage is that in which each half or portion of a pattern is attached

to a separate plate. This enables two men or sets of men to be working on the same mould, one on copes, the other on drags, a very great economy, which is necessary when a large output is required.

Metal Plates and Patterns.—These are necessary for the highest production, not only for machine-moulding, with which they are chiefly associated, but also in the hand-moulding of the smaller articles required in large numbers. Patterns are mounted on opposite sides of an iron plate (fig. 78), or on one side of separate plates. Weight is kept down by making the plates thin, say from $\frac{3}{8}$ in. to $\frac{1}{2}$ in., and by lightening the interiors of the patterns, though these provisions are of less moment when work is moulded by machine than when done by hand. Great care is necessary when fitting the pattern parts to their plates. Holes are drilled through both in place, and these receive dowel-pins or screws. In some cases a portion of a pattern may go right through a plate. All this work is rather of a special character, since patterns have to be finished in the lathe, the grinder, and with files and scrapes.

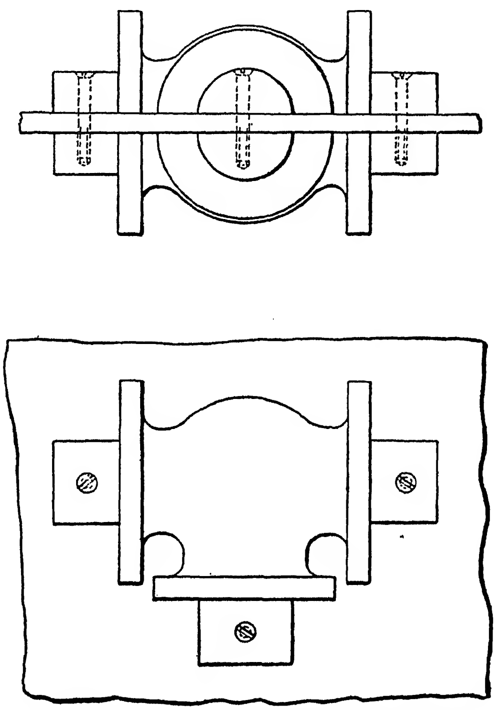


Fig. 78.—Iron Cock Pattern mounted on an Iron Plate

In a good many instances patterns are cast integral with their plates, or are made so by the method of their attachment (fig. 79). This is most

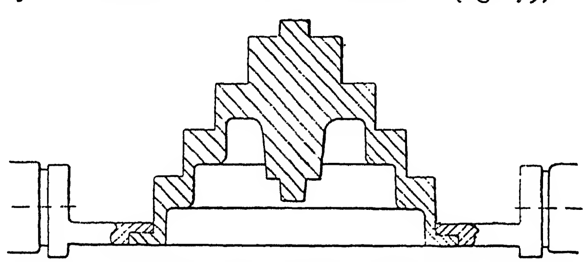


Fig. 79.—Iron Pattern mounted on the Turn-over Table of a Machine

desirable when the jointing faces are irregular, having depressions on one face and corresponding elevations on the other. These are readily cast, after which the parts must be smoothed with file and scrape.

One great advantage of plating is that several small patterns can be put

on a plate, which in ordinary moulds would be arranged by hand, and that all ingate patterns can be included, instead of cutting the channels laboriously in every mould (fig. 80). The economies of these last developments are such that the moulds for twenty or more small castings may often be made

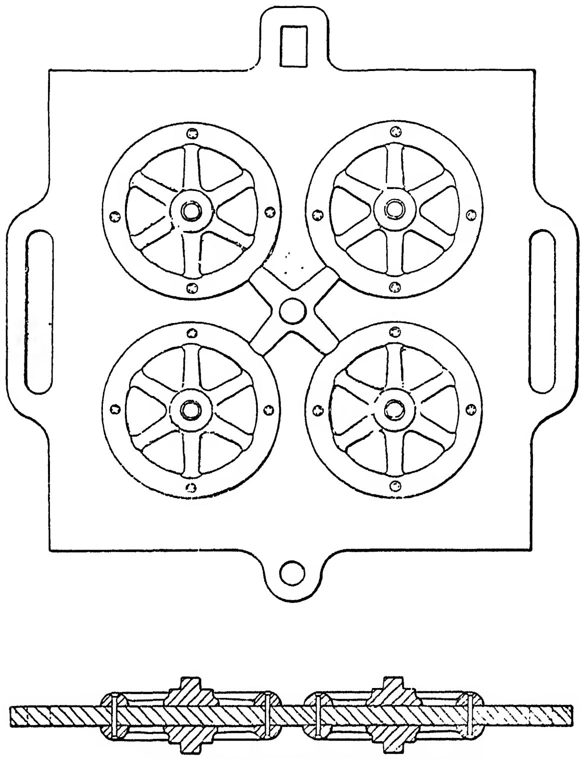


Fig. 80.—Four Patterns mounted on a Plate

in the time that would be occupied for one in hand-work by the ordinary method of turning over.

8. SECTIONAL AND SKELETON-LIKE PATTERNS

Both these are employed extensively for the largest castings when required in small numbers, in order to economize timber and labour. Extra work is always thrown on the moulder, but the question is one of relative cost. It is rather remarkable how much can be done with strickles, sweeping blocks, and skeleton frames, with the assistance of cores for dealing with the interiors. Often the pattern-maker has to spend a considerable time in the foundry assisting in the setting of parts and the checking of measurements.

Sectional Patterns.—This term includes a large variety of work, characteristic of which is that the provision for making the moulds ...sts of strickles, strips, sweeps, boards, bosses, facing pieces, prints, and

boxes, elements which in most instances bear only a remote resemblance ıe casting, and which have to be supplemented with drawings, sketches, ·erbal instructions. Nearly all this work is moulded in the floor and :red with a plain top, in which pattern parts may be set by measurement. ome cases the moulds are "open". Most foundry tools, such as loam es and rings, gaggers, back plates, core plates, and the larger moulding es are made thus.

The first stage in making moulds of these kinds is the preparation of a l bed, for which the .llel strips and the spirit-l are requisitioned, or a eping board is worked ıd a central bar. The :r method is usually em-·ed when a central boss, ılar facings, or shoul-ed sections are wanted. :se are formed by the e of the board, suitably iled, the top edge of the rd, parallel with the :om, being set horizon-/ with the spirit-level. e bed is vented to a ler bed below, and the ıld is made on it from sectional parts which the :ern-maker supplies.

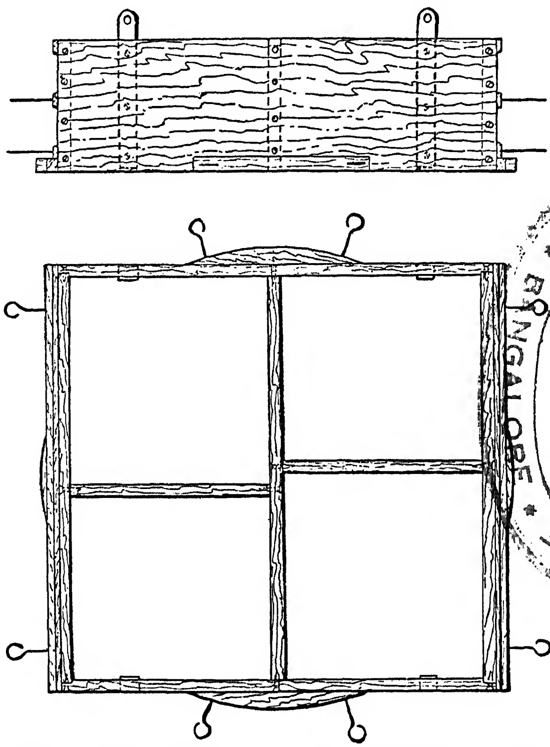


Fig. 81.—Skeleton Pattern from which all the Outer Mould is taken

Broadly, moulds may be ıped as rectangular or ular in plan. The first be produced by the aid hallow strips or of deeper rds set on the bed by ısurement, and retained in position with weights, against which the d is rammed. Any extraneous portions, as strips, lugs, bosses, or ıts, are set in their positions and rammed. A complete frame may be de (fig. 81) instead of separate strips, the outer mould being rammed ınd it and supplementary parts attached, thus relieving the moulder of responsibility of setting parts by measurement. If the interior is that of bbed casting, that is formed wholly with cores.

Moulds which are circular in plan are produced by the aid of "sweeped" tions. Any shape required can be readily imparted to these (fig. 82 and . As the length of the section is only 10 in. or 12 in., it has to be moved nd and reset for successive rammings. It is convenient to attach the ck to a radius bar worked round a centre pin. But this is not necessary,

since having a level bed swept, the block can be set and reset on a circle struck round with a trammel. It is held securely during ramming with a weight. The interior is formed with cores. The two methods just described are in common use for crane beds and centres which are of fairly large dimensions, but which are seldom ordered in considerable numbers.

With the exception of open moulds, only used in making foundry appliances and the roughest castings, a top box-part is necessary. When a sectional mould is made, the top cannot be rammed in its place on it, as is done over a complete pattern. Then it is either swept with a strickle and turned over on the mould, or it is rammed on a hard levelled bed of sand away from the mould, transferred to the latter, and set on it by measurement.

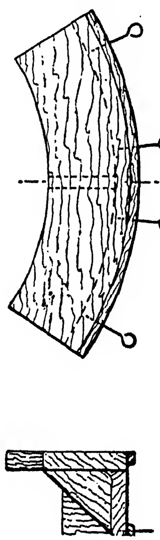


Fig. 82.—A Sweeped Pattern Segment, from which a ring is moulded

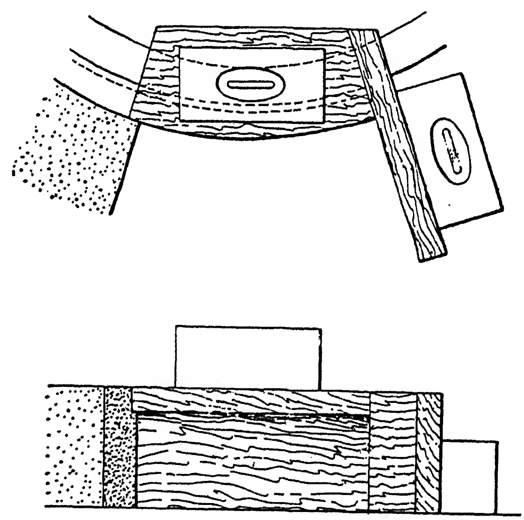


Fig. 83.—A Sweeped Pattern Segment set for Ramming an External Mould

The second method possesses this advantage over the first, that supplementary pieces, as facings, bosses, brackets, &c., can be laid on the prepared bed in their correct positions, and the top box be rammed on them. This is rather better than cutting away the sand in a strickled top and bedding them in.

Skeleton-like Patterns.—These differ from those just described in the fact that they include the correct outlines, the complete contours, and cardinal dimensions, but that the timber construction is not continuous. The outlines are represented by a series of ribs, which leave open spaces to be filled with sand. A large quantity of timber is saved, and labour is economized, with no disadvantages to set-off. The method is employed for large pipe-bends, large cylinders, condensers, and the casings of steam turbines. It is used also in making alterations to some patterns. Enlargements of portions of patterns and reductions in diameters of core boxes are

effected by fitting strips of the required thickness round the curves, leaving spaces between the strips about equal to their width to be occupied with sand.

Fig. 84 is a group of various pipe patterns, two of which on the left are skeleton structures. The cylindrical portions are represented by discs,

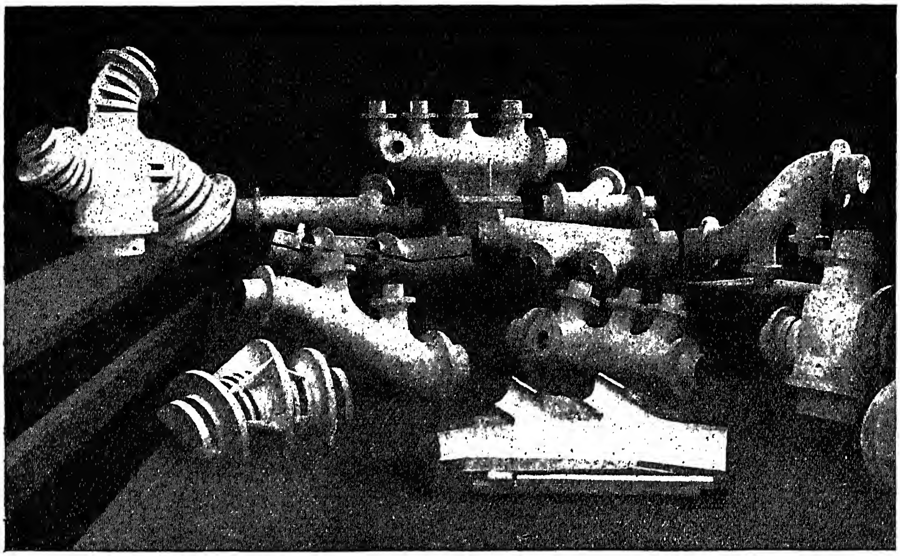


Fig. 84.—Group of Pipe Patterns, including Skeleton Structures

leaving spaces between, which are filled with sand at the time of moulding. The core prints are treated in the same way. The method is only used for work of fair dimensions, and the larger the patterns are the greater is the economy. These examples are by Messrs. Ernest M. Brown & Co.

CHAPTER III

Essential Machines

It is necessary to use the qualifying adjective, because some machines that are absolutely essential in some shops would be like white elephants in others, where they would be only partially employed. The larger the number of hands, and the more varied the kinds of work done, the more extensive is the selection of machines. Small shops handling specialities cannot afford to neglect the facilities that special machines offer. There is a wealth of labour-saving machinery now available, much of which is of comparatively recent growth, notwithstanding that pattern-work is still mainly that of the handicraftsman.

The Lathes.—These take the first place in all shops, since all the turning is done by the pattern-maker, who alone is competent to estimate matters relating to taper, jointing, loose pieces, and moulder's requirements generally. Lathes of from 6 in. to 8 in. centres are for common use. It is desirable to have one with a set-over headstock for taper-turning. The lathe has the ordinary tee-rest. The heads and rest are usually mounted on a wooden bed, but iron beds are common. Lathes of higher centres, say 12 in., and having long beds are necessary in shops where pipe and column work is done, and these frequently have a sliding rest. Large face work, as that of fly-wheels, gear wheels, &c., is done on one of the long bed lathes, fitted with a headstock spindle extended at the rear to carry a large face plate, and having a floor rest there. It is better to have a face lathe with a deep headstock bolted to a floor plate, which may also carry a loose poppet, and having a sliding rest on a stand mounted on a floor plate at the front. The chucks used are simple and few, comprising the fork, the bell, and the face plates of various diameters. The sheet anchor of the pattern-turner is the large assortment of wooden chucks, made and used for a variety of patterns, attached directly or through the medium of blocks, screwed on and recessed to receive patterns for rechucking instead of cutting into the solid plates.

The Saws.—The circular and the band saws should form part of the equipment of every shop. Suitable sizes of circular saws are from 14 in. to 18 in. diameter when new. The table must have a fence for cutting strips to uniform widths, and a canting movement to the table is desirable for sawing lags to a bevel without waste of material. A rising and falling table is of value for rebating and shouldering. The band-sawing machine is indispensable for cutting curves, and a tilting table permits of cutting bevelled edges.

The Planing Machines.—Though a number of small shops do not include these in their equipment, they are great time-savers. There are three chief designs, the first machines one surface only, the second machines parallel surfaces, and the third, by adjustments of the lower table, imparts taper. So much of this kind of work has to be done in the pattern-shop that the fully equipped machine soon recoups its outlay. The procedure is to plane one face of the stuff over the top table, taking care not to exercise too much pressure on the board, especially when it is thin and liable to spring and produce a winding surface. The trued face is then placed on the lower table, and carried along by the feed rollers, while the upper face is planed with the revolving cutters. A fence is fitted to the top table for use when the edges of boards are being planed.

The Wood Trimmer or Mitre Cutter.—This machine is hand-operated through a lever, and saves a good deal of time otherwise spent in planing ends of shorter pieces, held in the vice or laid on the shooting board. The fences, two in number, for right- and left-hand cutting can be set to any angle. Some of these go on a bench, others on floor-stands. The knives in machines of different dimensions will take a good range of work, from 7 in. long by 4 in. thick in the smallest, to about 18 in. by 5 in. in the largest.

The Mechanical Wood-worker.—No single machine has effected so great economies in certain departments of pattern-shop work as the Mechanical Wood-worker, developed by Messrs. Wadkin & Co. of Leicester. Previous to its advent, the statement that a single machine would tackle the cutting of the teeth of gear wheels, the shaping of sweeps, of bend pipes, and of the most intricate core boxes, would have been received with incredulity. Yet this machine performs these functions, in addition to others of a more general character.

The machine (fig. 85) is supported on a main frame, curved deeply in-

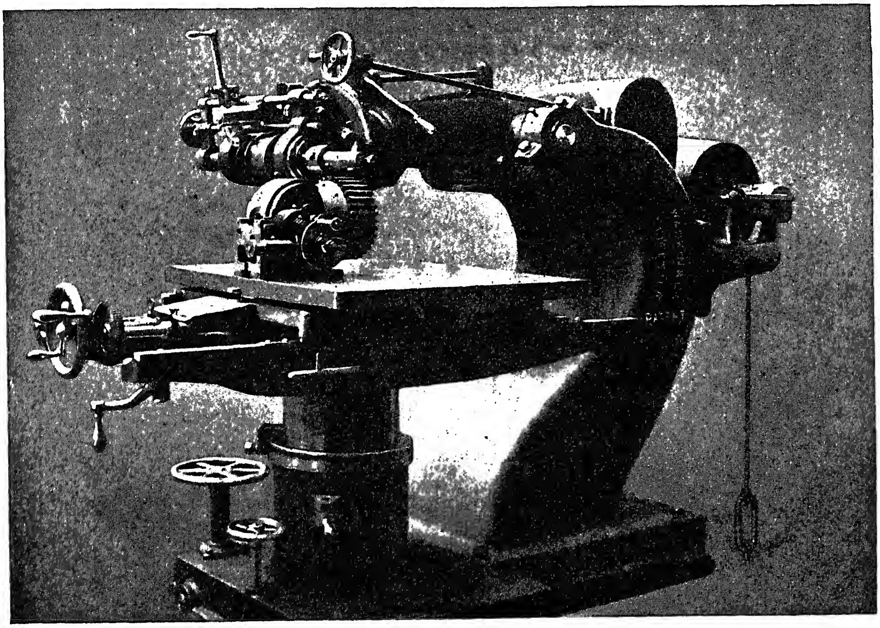


Fig. 85.—Mechanical Wood-worker operating on small Spur Wheel. The whole of the teeth cut in eight to nine minutes

wards to receive articles of considerable width. On this the overhanging arm carrying the spindle-head floats up or down on sensitive bearings, with a range of movement that will permit of its being raised above the horizontal position, or lowered until the spindle is below the level of the work-table. It can be set exactly horizontally or in any intermediate position.

The spindle head, at the outer end of the arm, swivels between the vertical and horizontal, and can be locked in each or any intermediate position. It carries a spindle and a chuck solid with it, ground to a No. 4 Morse taper. It runs on two double rows of Hoffman ball bearings in dust-proof housings. It can be rotated in either direction by means of a lever, a feature which is of much value because it enables cutting to be done with, instead of against, the grain. The spindle is fed to the work quickly by a hand-lever, and slowly with a fine screw adjustment by a hand-wheel. The lever motion is controlled

by a spring plunger taper pin working in holes in a quadrant and having an index, by which the depth of cut may be predetermined and the cutter gradually fed into the work.

The work-table is massive, and is provided with tapped holes to secure holding-down clamps. It has two motions at right angles, one operated by rack and pinion, the other by screw and hand-wheel. It is mounted on a pillar that travels along a runway which is bolted to the main frame. The base of the pillar runs on anti-friction rollers, and is moved by rack and pinion. The table can be turned through a complete circle on the pillar and locked,

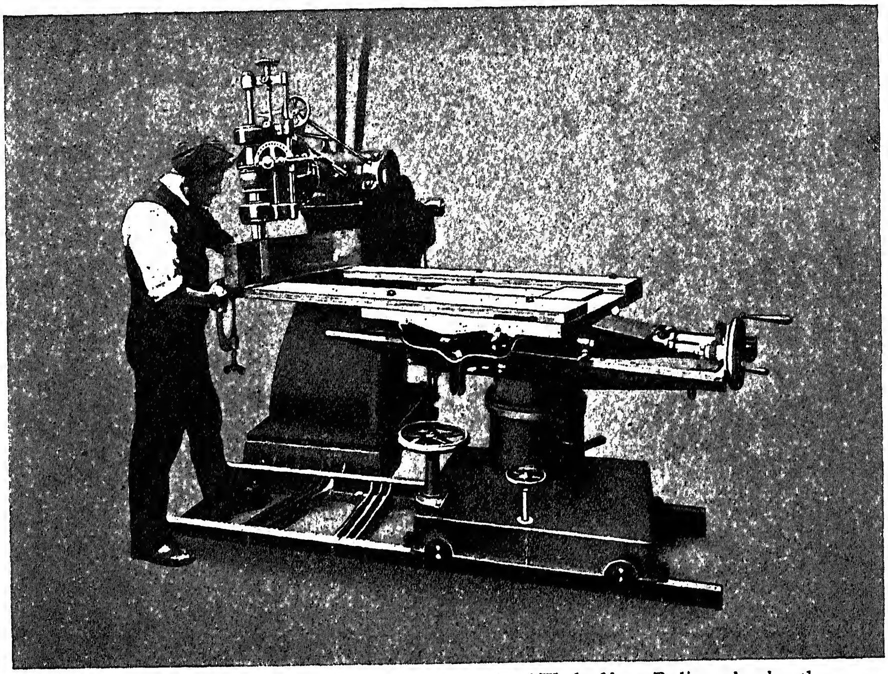


Fig. 86.—Mechanical Wood-worker operating on Sectional Work of large Radius. Any length may be operated upon

and can be raised and lowered. An auxiliary table turning about a centre pin is provided for small work.

The Range of Work Done.—Fig. 85 illustrates the cutting of the teeth of a spur pinion, done in about nine minutes, a fair day's work if done by hand. It is held in the universal head that is used for spiral and helical gears. A gear-cutting fixture is inserted in the spindle, carrying a fly-cutter having the same section as the tooth spaces.

Another large group of work is that which concerns the cutting of sweeps, done at the bench with gouges, spokeshaves, and planes. They are cut with an adze block (fig. 86), the spindle being set vertically, or canted slightly if taper is required. The table carrying the sweep is moved around the curve, round the centre of the top table if of moderate radius, or attached to a light former of wood as in the figure for larger radii, the table being moved along

the runway past the front of the main frame. Sweeps 14 in. deep can be cut. Pipe bends are treated similarly. Fig. 87 shows a half-pattern of small radius carried directly on the table. The fly-cutter has nearly the same sectional curve as the bend, and operates on both sides in succession. At the same setting a regular curve can be combined with a straight length. When core boxes for bends are being cut, the same method is adopted, the cutter having a semicircular contour, and the half-box being carried round a radius or along a straight line as required. But boxes for branch pipes

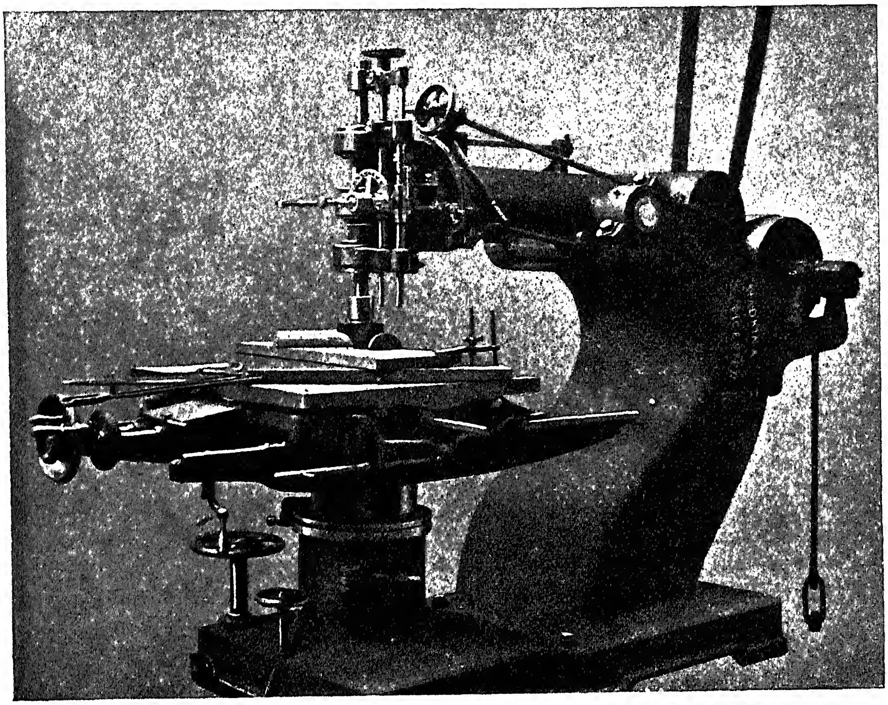


Fig. 87.—Mechanical Wood-worker operating on small Section as Pattern Bend of small Radius

Any section up to twenty-four inches can be operated upon, and any radius. The whole segment of a circle may be operated, and straight parts to any extent may be left at either or both ends of bend.

and those with recessed portions are cut with the spindle set horizontally (fig. 88), with cutters of the sectional shapes required.

Miscellaneous Machines.—The circular and band saws, the various machine cutters, and the bench edge tools have to be sharpened and kept in good working order. Though often done without mechanical aids, these become necessary in the large shops. On the regular setting of circular and band saws their efficiency mainly depends. Circular-saw teeth can be set in one machine and evenly sharpened in another. Band-saw teeth are set and sharpened in one machine. The cutters for planing machines and other kinds are ground while held in a fixture traversed past the face of an emery wheel of cup shape. For the small machine cutters and for hand-

tools, grinding wheels and circular oil-stones are obtainable. Included in the equipment of some shops is the conical oil-stone for sharpening the concave bevels of paring gouges.

All the machines in a shop, the lathes excepted, should be in the charge of a man or men who alone operate them and are responsible for their

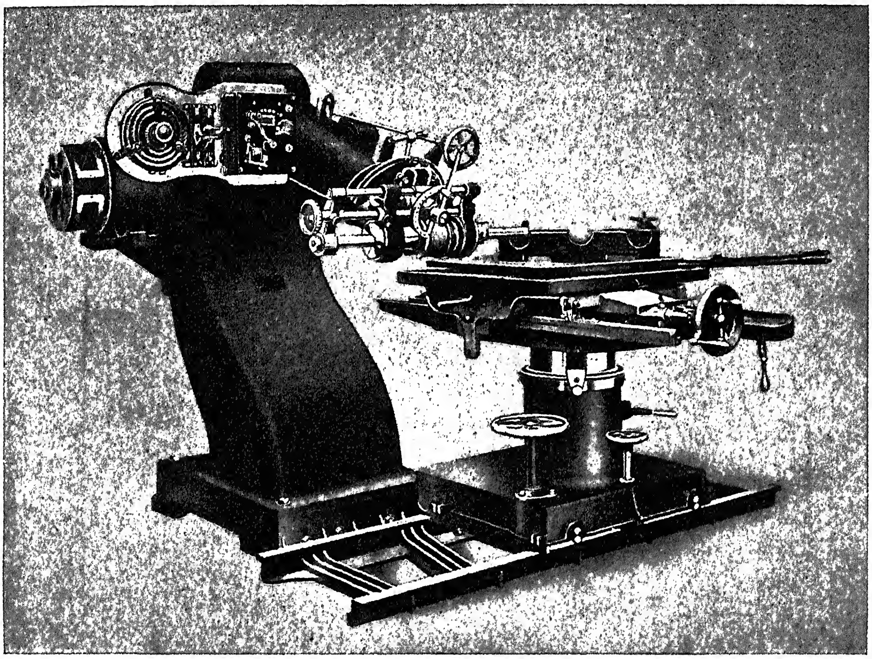


Fig. 88.—Mechanical Wood-worker operating on Three-way Valve Core Box with numerous Internal Chambers

The core box shown was completed in forty-five minutes. Approximate time by hand forty-five hours.

efficiency. This is both economical and safe, since circular saws and planing-machines are fruitful of accidents to inexperienced hands. The lathes are used by all the pattern-makers, who also grind their own tools.

CHAPTER IV

The Shop and the Stores

The lay-out of the pattern-shop does not reveal those aspects of interest which are associated with the machine-shop and with some of the later foundries. The real attraction centres in the work under construction. The lay-out is similar to that of the carpenters and joiners. Rows of benches disposed across the shop accommodate two men each, working at opposite

sides. One long, wide bench with several vices is reserved for the larger patterns when the work is of such a character as to require them. Machines are arranged along one side or one end of the shop, in close proximity for convenience of driving and of operation. The circular saw and the planing-machine must have unobstructed spaces at front and rear for the movement of boards. The most suitable drive is a gas-engine or an electric motor, either of them driving a length of shaft from which the machines are driven. If metal pattern-work is done, this engages a separate department, or is relegated to another building. When large patterns are constructed, large doors are required at one end of the shop. Whether the shop shall occupy a ground floor or an upper story is a matter of no importance. A ridge roof with north light is desirable, or, having a ceiling, side windows must be of sufficient area. The shop should be heated with hot water, unless a regular hot air and ventilating system is installed in the works, which may include the pattern-shop.

The timber should be stored adjacent to the shop. It is stripped during seasoning, but may be laid edgewise when ready for use. As timber is expensive, economy can be practised by storing all odds and ends, which are numerous in pattern-work, on racks at one end of the shop. The selection of suitable fragments will often save the expense of cutting into a board. Core prints are turned in quantities for stock by the apprentices. Some are nailed on patterns, but a fair proportion are turned with studs of some standard diameter to go on bosses for gear wheels and pulleys. Wooden dowels may be stocked, but the metal kinds are more durable. Wooden fillets, hollows, or angles are required for all patterns except the roughest, but those of leather are supplied to the trade. Pattern letters of various sizes and shapes are made in lead, tin, and brass, but these are better bought. Rapping plates to suit all patterns are purchased. All these are kept in the shop stores.

Method of Working.—The organization of the machine-shop is not represented in the pattern-shop. Methods have been modified by the introduction of the machines just now described. The result is that much laborious hand-work formerly done on the bench is performed much more expeditiously on machines. All the hands are trained craftsmen, who have served a lengthy apprenticeship, and who work under the direction of an experienced foreman. And although the practice in the large shops is to keep certain men or groups occupied with definite tasks, these are men with a general training, who have drifted into specialization.

Men are paid by time in most shops. The variable character of the work done, the fact that the greater portion of it is handicraft, that alterations are sometimes seen to be desirable during its progress, and that one foreman is easily able to keep the entire shop under observation, are causes that favour payment by time rather than by the piece.

The method of constructing a pattern is settled by the foreman. When uncertainty exists as to the selection of the best among alternative methods of moulding, it is well to discuss the matter with the foreman of the foundry.

During the progress of the work he keeps it under observation, both with a view to save labour and to detect error on the part of the workman, but without obtrusive interference with the idiosyncrasies of the craftsman, who often has his own peculiar ways of doing things. When the pattern is complete the foreman measures it carefully before sending it to the foundry.

To deal with the many thousands of patterns that accumulate, some form of registration is essential. A pattern register is kept by the foreman, in which is entered the actual name of every piece and the order for which it was made, but opposite the name are letters and numbers, and these are stamped on the patterns. The letters are those of the alphabet, the numbers, commencing with 1, run up to a predetermined limit, 1000 or higher. These are stamped on the main pattern, on every loose piece, and every core box belonging to it. If any portions stray in the foundry or in the stores, the letters and numbers indicate at a glance the pattern to which they belong.

Written orders are sent with each pattern into the foundry, with the date, the order number, and the number of castings required from it. Error in moulding, as it affects faced portions or prints and bosses, is sometimes guarded against by the use of distinctive colours. Thus, while the patterns are protected with yellow shellac varnish, portions to be faced may be uniformly painted black or red. Core prints may be painted one colour to distinguish them from metal.

The Stores.—These occupy large areas, since patterns accumulate rapidly, and many of them with their boxes are bulky. A storied building is usual, the heavy work being in the basement, the lighter on floors, for which tiers of shelves are provided, the widths and spacings of which have to be in accordance with the general class of work done. Two general systems of storage are adopted. In standard work all the patterns of a set are placed together, the light and heavy. As these are never altered for different orders, they need not be checked over, but sent complete into the foundry. But patterns that are not strictly standardized are subject to alteration from time to time, and this renders measurement and checking for loose pieces and core boxes necessary for all new orders. For these the practice is to put all patterns of one class together, from which selections for casual orders can be quickly made. The letters and numbers stamped on patterns and their parts show for what previous orders they have been used, and with what alterations. All the shelves are numbered, and the number of the shelf on which a pattern is stored and the number of core boxes are entered in the register. Metal patterns are kept in a separate place, many being hung on the foundry walls.

FOUNDRY WORK

BY

JOSEPH HORNER, A.M.I.Mech.E.

Foundry Work

Introductory

The Work of the Foundries: What it Embraces.—Since the major portion of this work deals with the products of the iron foundries, these must receive the principal attention in this article. And it must be remembered that the essential methods of the iron moulder are also those of the steel, brass, and malleable cast-iron foundries. The details in which these differ from one another are so important that each engages the services of its own specially trained craftsmen, who would have much to unlearn, and learn, if they should attempt to take service in one of the shops of another group. But what all have in common are the fundamental facts: that liquid metal is poured into a matrix of sand, usually prepared from a pattern; that the moulds are all subject to the same laws that control liquid pressure and the shrinkages of metal; that the various methods of making moulds, with one or two slight exceptions, are employed in all foundries alike.

Metal Moulds.—While the castings poured into sand moulds include probably 90 per cent of the total quantity of castings made, much the larger portion of these being of iron, there is another and a steadily growing group, the moulds for which are of cast iron or steel. It embraces the chilled castings, and the more recently introduced permanent moulds for pipes, and the extensive practice of die-casting, employed for small, more or less intricate articles made in the softer alloys, and required in very large quantities.

Subdivision of Tasks.—In the very extensive group of iron foundries, there is much subdivision of tasks. This occurs in all the large shops, and in many of those of small size. The product and the men are specialized. The great subdivisions are: moulding in green sand, dry sand, loam; core making and machine moulding, each often classified under light and heavy. In the machine department, further economies are effected. One man makes bottoms only, another tops, while a third will core and close, ready for a fourth to pour. A few years ago there were craftsmen to be found in most shops who were competent to work in green sand or loam, in light or heavy moulds, and at core making, while when occasional casts in brass were wanted, an iron moulder would take on the task. These

made excellent chargemen and foremen. They only survive in the ranks of the older men. Each department now employs its own sets of hands, producing the same classes of castings the year through. Moulders, like machinists, are specialists. Only in the general jobbing and repair shops do exceptions occur.

Foundry Metal.—This includes cast iron in its numerous grades, the steels, malleable cast iron, the immense groups of brasses and bronzes, alloys of copper, aluminium and its alloys, and the varied die-casting alloys. Many of these are now graded by analysis and by the scleroscope, instead of, as of old, by the foreman estimating by the aspect of fractured surfaces, supplemented by test bar results. For melting, the cupola furnace occurs in many excellent designs, with its equipment of fan or blower, blast gauge, platform, weighing machine, receiver or ladles. Brass-melting furnaces are coke-fired, or oil- or electrically-heated, with provisions for utilizing the waste heat. Steels are melted in convertors of large and small capacities; malleable cast iron in air furnaces.

Sands.—In a foundry equipped with modern appliances, the preparation of sands is done wholly with machinery. It takes charge of them at every stage, drying, crushing, grinding, mixing, sifting, and conveying. Suitable mixtures have to be graded for green, dry, core, and loam sands, and again for light and heavy moulds. They differ also for steel and iron, and facings for the moulds are varied. For this work, a complete mechanical plant is often now installed.

The Treatment of Castings.—This, colloquially denoted by the terms "fettling" and "dressing", engages, in the big advanced foundries, a large quantity of machinery and plant, doing work that was formerly all performed by hand methods. It includes: machines for severing the runners, with chisels or with saws; grinding wheels; pneumatic chisels for the removal of fin marks and roughnesses; tumbling barrels for smoothing castings by attrition; and, in the later plants, sand-blasting machines, now made in many designs to deal with castings of all dimensions. In the more complete plants, dust-exhausting systems of pipes with exhausters are installed.

To deal adequately with all the aspects of foundry work outlined in the preceding paragraphs is obviously not practicable. Neither does it seem to be called for. Each single subject is now highly specialized. The foundry craftsman is only directly concerned with and responsible for the preparation of the moulds. The sands are prepared for his use, the metal is graded, suitably melted, and brought to him, the patterns are prepared to be moulded in a certain way, from which no essential departure can be made, and he has no further concern with the castings if they are turned soundly out of the moulds. Bearing these facts in mind, it is proposed to occupy the major portion of this article with the subject of the preparation of moulds required for the metals and alloys, leaving the collateral matters to be dealt with in a summary fashion.

CHAPTER I

Moulding in Green Sand

The term " green sand " does not denote any one of the specific mixtures used, but it signifies that the sand is moistened and rendered coherent with water, so that it becomes sufficiently self-sustaining to retain the shape imparted to it by the pattern, and to resist the pressure of molten metal. It differs therefore from moulds made in dried sand and in loam, and from cores, which are desiccated. By far the largest proportion of moulds, large and small, is made in green sand. As there is no drying process, fuel and time are saved. Green-sand work embraces three systems of working: open sand, bedding-in, and turning over, or rolling over.

Moulding in Open Sand.—This is but a crude and very elementary method, and one which is of extremely limited application, being almost exclusively employed for making foundry appliances, loam and core plates, back plates, moulding boxes, and sometimes balance weights for cranes. It signifies that the mould is not covered with a cope, and the consequence is that the upper surface of the casting so poured is left rough and uneven as the metal solidifies. The necessary details may be stated briefly.

A Levelled Bed essential.—If the bottom of an open mould is not level, the thickness of the casting will not be equal all over. The bed is levelled by bedding two parallel straight-edges—"winding strips"—in the sand of the floor, levelling them lengthways with a spirit-level, and, in relation to each other, with a parallel straight-edge set across them, and a spirit-level. The sand is flat-rammed a little higher than the top edges of the bedded-in strips, and then strickled off level by them. On this bed the mould is made, seldom from a pattern, but usually from a skeleton frame, or as often from sectional pieces. No venting is required as in closed moulds, and no specific sand mixtures, the moulds being made in the floor.

The Formation of Mould Outlines.—If these are produced from entire patterns, as core grids generally are, the pattern is laid on the levelled bed, and the sand rammed around and within it, and strickled off. In most cases some portions have to be stopped-off to suit various core outlines. In others, a grid larger than the pattern is required. Here the pattern is rammed in one position, then removed to another adjacent position, and rammed again. Generally, open moulds are constructed with sectional pattern parts. The outlines are marked on the levelled bed by the moulder or pattern-maker. External portions are rammed against short sweeped pieces, moved around and rammed in successive lengths. Large central holes are rammed against concave sweeps. Small holes are formed with cores, measured in, and held down with weights. Straight sides are rammed against straight strips. In all this work the depth of the mould exceeds that of the casting thickness by from $\frac{1}{2}$ in. to $\frac{3}{4}$ in., and flow-off gullies are cut at the height corresponding with the thickness required. This is necessary, because it

is not possible during pouring an open mould to stop at the precise thickness. The metal is not poured directly into the mould, but into a shallow basin at one side.

Numerous adjuncts are located in these moulds: loam plates, core plates, and solid grids with prods or prongs distributed over portions of their surfaces. A pattern prod carrying say half a dozen prongs is pushed by the moulder into adjacent positions without any particular regard to

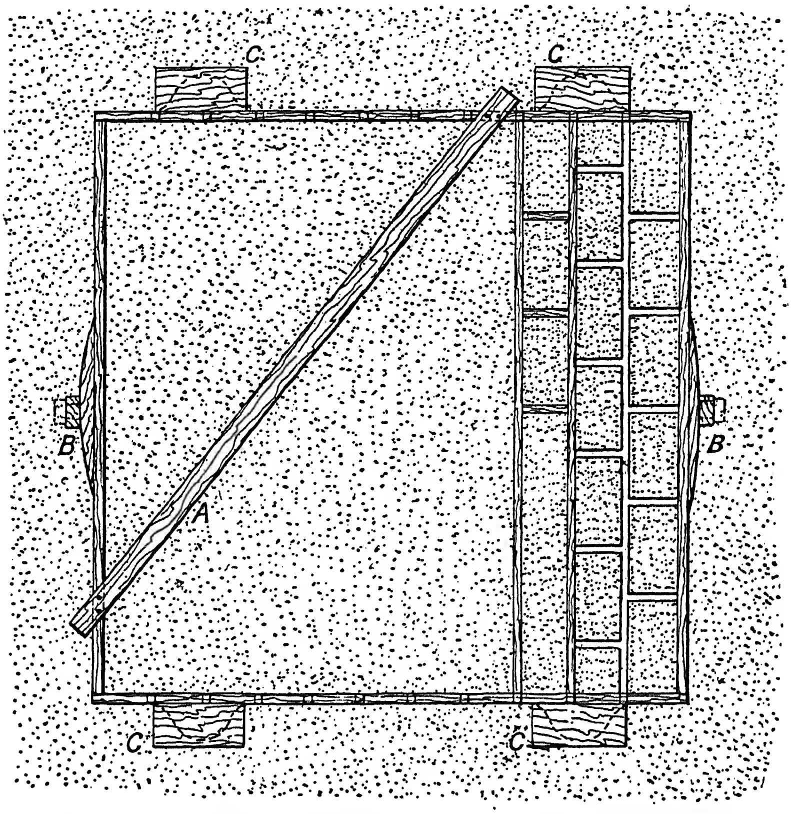


Fig. 1.—Shows Pattern Frame for Box with Loose Bars moved into successive Positions

A is a diagonal to keep frame square. B, Provision for swivels. C, Prints covering lugs for pins.

exact spacings, the prods therefore being cast with the plate. Wrought-iron rods of various lengths and outlines are thrust into the mould to be cast into grids. Long rods with eyes are suspended in the mould, so that the metal runs round them and amalgamates. Nuts are cast in when grids have to be retained in their places with screws. Looped handles are cast in for the lifting of cores.

Large heavy moulding boxes are commonly cast in open sand. The work is done in successive stages with the help of a limited number of parts. The pattern box sides are framed entire, but three bars or stays suffice if

their outlines are uniform. These are moved along in rotation, one remaining in the sand to afford support while other two are being rammed (fig. 1). Sectional patterns for fittings for boxes of various sizes and types are stocked, and selected as required. These include box ends with prints for the iron swivels, and core boxes for looped handles, and for the lugs in which the pins are fitted.

Moulding by Bedding-in.—This embraces a very extensive volume of work done, the essential characteristic of which is that it is moulded in the foundry floor instead of in a box. The mould is covered and closed with a cope, through which the metal is poured. As there is no bottom box with locating pins, the cope has to be set with stakes driven into the sand of the floor. Bedding-in is mostly adopted in the largest work. The reason is, that the turning over of massive boxes with their contained sand would be very inconvenient, and in some foundries impracticable. The cost of the

A

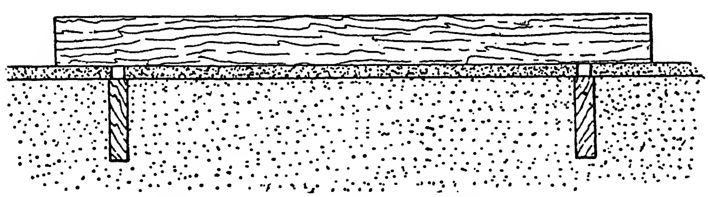


Fig. 2.—Strickling Facing Sand on a Mould Bed

A, Thickness of facing.

boxes also would bear too high a proportion to that of the castings, which are seldom wanted in large numbers. And provided reasonable care is exercised, castings can be made as satisfactorily by bedding-in as by turning over.

Variations in Details.—Methods of procedure are modified by the shapes of patterns. If these have level lower faces and broad areas, a levelled bed is strickled under the guidance of winding strips, as described in the making of open moulds. The vents from the large areas must be driven down into a cinder bed, to be brought away through large vent pipes extending from the bed to the outside of the mould. Instead of using winding strips for levelling, the horizontal edge of a sweeping board can be worked round a central bar, a method which is adopted when central bosses and annular facings have to be produced in the bottom. On the bed, first prepared, the pattern is set and rammed. This may either be complete, or a skeleton outline, against the outer faces of which the mould is rammed, leaving the interior to be formed with cores.

When patterns have irregular outlines, and parts projecting into the bottom, such as deep flanges, ribs, bosses, and lugs, each portion has to be treated in detail if lumpy castings are to be prevented. If the pattern is very diversified in outline, a level bed is of no value. If its main web is flat, the bed is required. In each case the floor sand is prepared by digging and flat-ramming, and over it a thickness of 1 in. or more of facing sand is

sieved. A fairly even quantity may be ensured by laying two strips on the floor sand, say 1 in. thick, and strickling the facing sand level with these (fig. 2). The pattern is bedded on this, and driven in with blows of the mallet, applied with sufficient firmness to leave its outlines impressed on the bed. Where the projecting portions are beaten down, the sand is rendered harder than elsewhere, and the casting might become scabbed in consequence. The pattern is removed and the hard sections of sand are loosened with the trowel and the pattern bedded again, frequently more than once. More facing sand is added where necessary, loose portions are tucked under with the hands and the pegging rammer, and any necessary venting is done with the pricker. In plain patterns having narrow sections or semicircular outlines, the whole of the work may be done by tucking the sand under, without removing the pattern. The pipe in fig. 3 can be moulded by tucking under.

Formation of the Cope.—Any plain top box part of a size suitable to

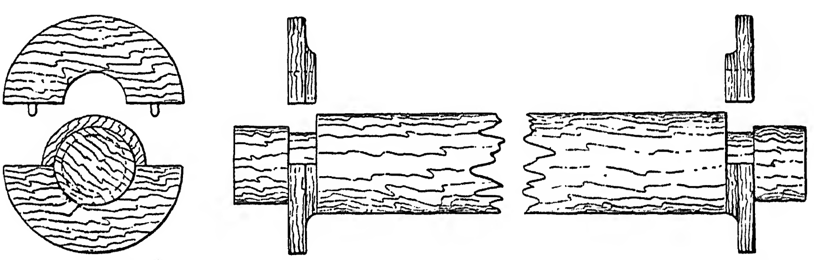


Fig. 3.—Iron Pattern of Pipe with Flanges of Wood suitable for Bedding-in by tucking Sand under

cover the mould is selected. It is set in its position with four stakes, that take a bearing against joggles on the box sides, or against its lugs. It is then rammed on the pattern, removed, turned over, the mould finished and the box replaced, guided by the stakes. The cope is then loaded with weights before pouring, since there are no box pins to be cottered. As the top is plain, the stays stopping short of the joint face, the sand in any deep recessed portions of the pattern has to be carried with lifters hung from the stays, or, in other cases, when the deep portions have large areas, grids are suspended from the stays to carry the sand. When moulds are so long that they cannot be covered with a single top, two boxes are laid side by side. Long, flimsy patterns give trouble when bedded-in, because it is difficult to prevent bending and winding. The progress of the work is therefore checked constantly with straight-edges and winding strips.

A large volume of work is done in the floor when, instead of complete patterns, frames or sectional elements only are used for the exterior portions. This, though not strictly a process of bedding-in, is allied to it, since a bed has to be prepared, and vented down to a cinder bed, and the mould is covered with a plain top. Bedplates of rectangular and circular outlines are often made in this way. When copes are not plain, but contain bosses and facings, and there is no complete pattern with a top boarded over to ram

on, the cope is rammed first on a dummy sand face. A level bed is swept, corresponding with the mould joint, the various pattern pieces are set on

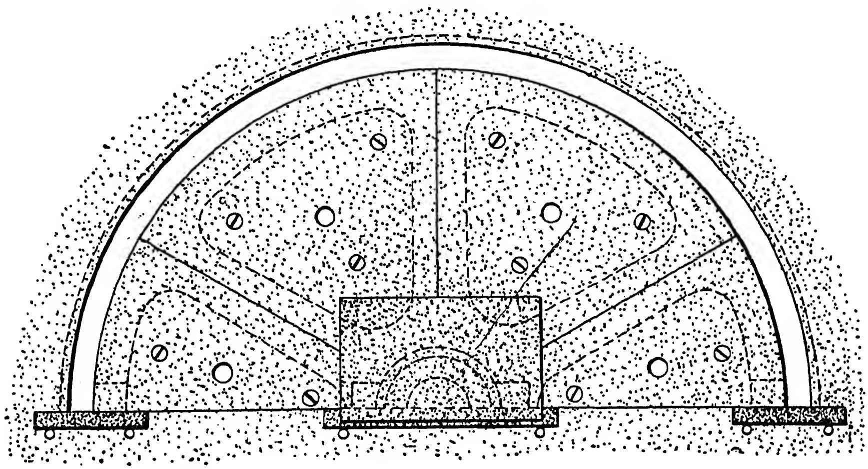


Fig. 4.—Half Fly-wheel Mould made without Pattern, using a Sweep Piece and Cores

this by measurement, the cope is rammed over them and removed, the sand in the bed dug out, the mould made, and finally covered with the cope, which is guided into its original position with the stakes.

Though these large moulds are made in green sand, the surfaces are often hardened slightly by the process of "skin-drying". A devil containing burning charcoal or coke is suspended in the mould, which drives off a portion of the moisture. But for dried moulds, a different mixture of sands is necessary, and these are contained wholly in boxes.

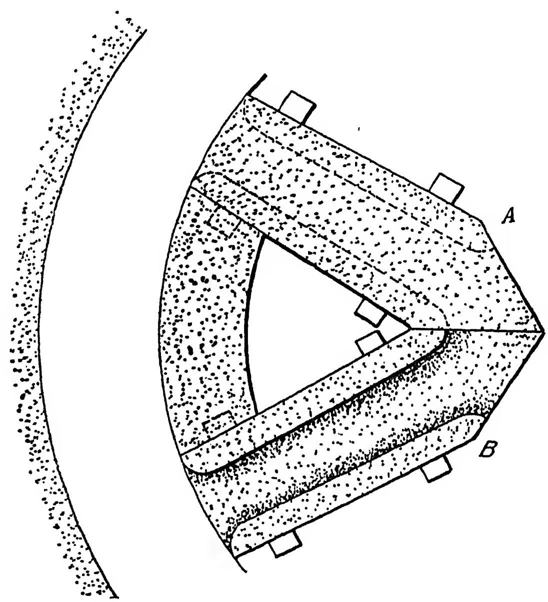


Fig. 5.—Portion of Fly-wheel Mould

A, Half cores closed. B, Half core open.

Figs. 4 to 9 illustrate examples of work made in the floor. Fig. 4 is a half fly-wheel mould. The rim has been formed with a sweeped piece, and the arms with cores. The joint faces of the rim and the boss are closed with pieces of loam cake. Fig. 5 is a portion of a fly-wheel,

made with a sweeped piece for the rim, rammed against outer and inner curves, and having the arms formed with half cores jointed in their middle plane. The halves are closed at A, the lower half core is open at B. The projections seen are the sides of the grids. Bosses only have to be bedded in bottom and cope.

Fig. 6 is a casting moulded without any pattern portion except a sweep that forms a circular print, shown at A. Half a dozen cores (fig. 7) are made in the box (fig. 8), which, when laid on a level bed, produce the holes for the lever bars, and the spaces adjacent for lightening. A central boss has to be set in the bottom and cope.

Cores, bosses, and facing pieces often have to be set in by measurement. In some cases a templet is useful. An example is given in fig. 9, used for making print impressions in the bottom of the mould for a boilermaker's levelling block. The holes are first pitched and bored correctly in the templet, then the print, having a shoulder to determine the depth, is thrust into each hole in succession. The half holes round the edges of the templet are laid against the cores already inserted.

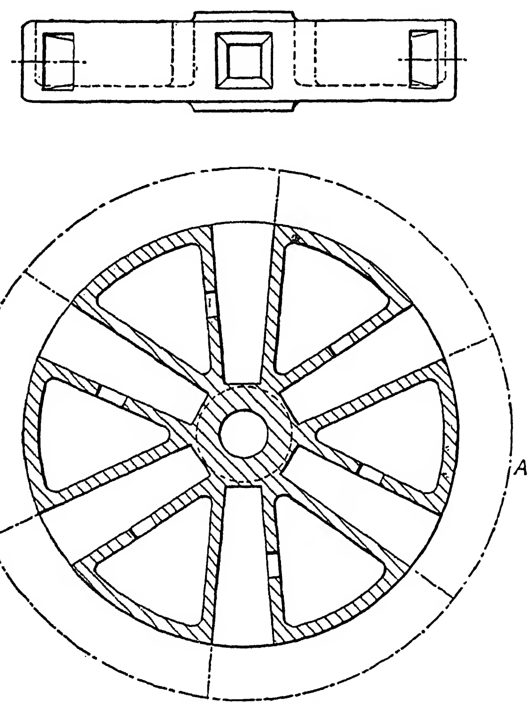


Fig. 6.—Casting of Capstan Head to receive the Bars
A indicates a circular print and the joints of cores.

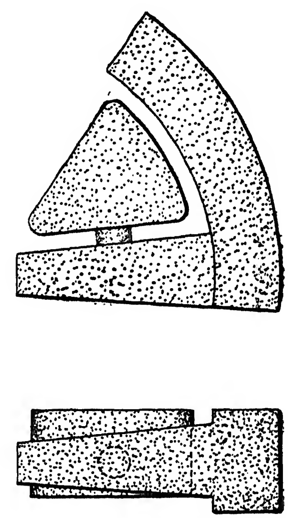


Fig. 7.—Core for Capstan Head

Moulding by Turning Over.—This method requires at least two box parts, a top and a bottom, within which the mould is wholly contained, and a middle part is frequently included. It is, of course, the ideal method, because both faces of the pattern are treated exactly alike, each being subjected to direct ramming of the sand against it. This is therefore the

most universal method of moulding. Its value is most evident when patterns have very intricate outlines, undercut portions, deep projections, loose pieces, bosses, ribs, and so on. These can be evenly rammed directly, and parts which are troublesome to deal with when bedding-in are more accessible.

In the usual practice, that is, apart from the employment of joint boards or of plates, the pattern is embedded in a body of sand in the top box, which is thrown out after the joint face has been made. But it is only shovelled in and made sufficiently hard to ram on, so that the loss of time is not of much importance in the work of the general shop. The following states the typical sequence of this work. The top box part is laid with its top face on the floor, is filled, and roughly rammed with sand up to its joint edges, and the top side of the pattern is bedded in this, until the joint edges of the pattern coincide with the sand joint, which, whether plane or irregular, is shaped and sleeked with the trowel. Parting sand is strewn over this, and the bottom box part is placed over the upstanding pattern, and cottered to the top box. After ramming and venting, the two are turned over together, the bottom being brought to a level bearing on the sand floor. The temporary sand is knocked out of the top box, then replaced on the bottom, and rammed permanently. If a middle part is used, this being interposed between the top and bottom, an additional joint is required.

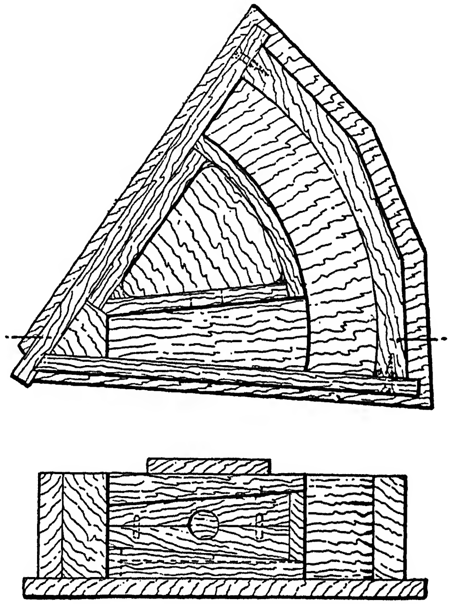


Fig. 8.—Core Box for Capstan Head

The advantages of direct ramming are secured in other ways where boxes are not turned over, but the treatment properly belongs to plate and machine-moulding.

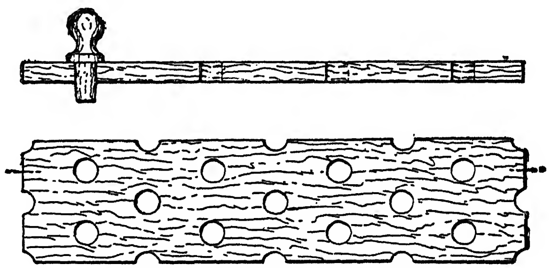


Fig. 9.—Templet for setting Core Prints

Although it is usual to joint patterns in the plane of the mould joints, the practice is far from universal. The smaller the patterns are, the less frequently are they jointed. Brass moulders seldom use jointed patterns except in the larger sizes, but lay solid patterns in odd-sides. There is less risk of the occurrence of lapping joints than when top and bottom portions

are located with dowells, and in long patterns like that in figs. 3 and 10, if made in timber, warping in the transverse and longitudinal directions

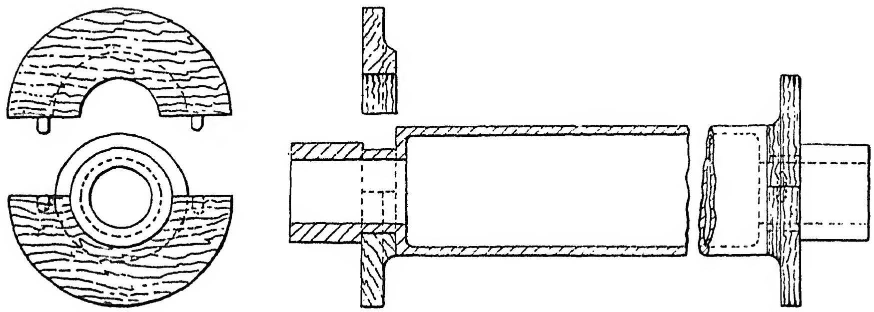


Fig. 10.—Pipe Pattern not Jointed for Turning Over. Shows method of fitting flanges loosely in grooves

is less liable to occur than in a pattern that is made in two portions. But as the top box must then be lifted off the pattern, it is better to leave the flanges loose, because they have vertical faces.

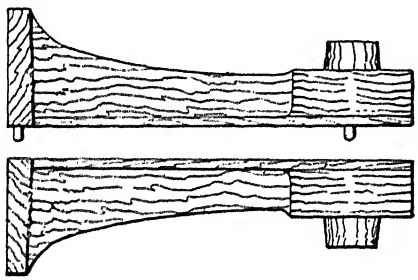


Fig. 11.—Jointed Bracket Pattern

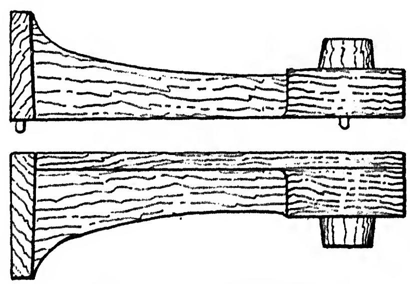


Fig. 12.—Jointed Bracket Pattern

Three examples of brackets in which the jointing coincides with that of their moulds are given in figs. 11 to 13. In the first the joint is along the middle plane of the web, in the second along its top face. If these were not parted as shown, the lifting of the cope sand off the vertical rib would fracture the sand, to avoid which the rib alone is often left loose, and the upper portion of the boss and of the foot made fast. In fig. 13, the upper boss and its bracket, shown dowelled, are often made fast. Each of these patterns might alternatively be moulded sideways, that is as they lie on the paper.

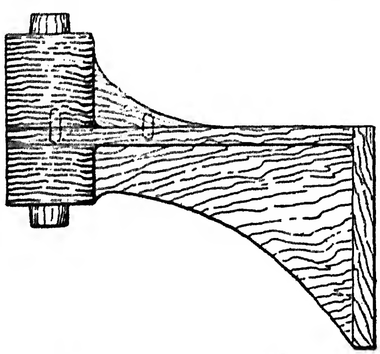


Fig. 13.—Jointed Bracket Pattern

Fig. 14, the radial arm of a drilling machine, should properly be jointed in the plane *aa*, and moulded by turning over, but bedding-in offers no special difficulty. The prints for the column core are dotted at A, A; the overhanging portions of the facing for the saddle must be loose, as at B, B.

Fig. 15 is a fusee drum for a derrick crane, having the ratchet cast at one end. The ratchet is made in a core, the print for which is outlined at A. Fig. 16 is its mould, cored ready for pouring. Reference to some of its details will follow presently.

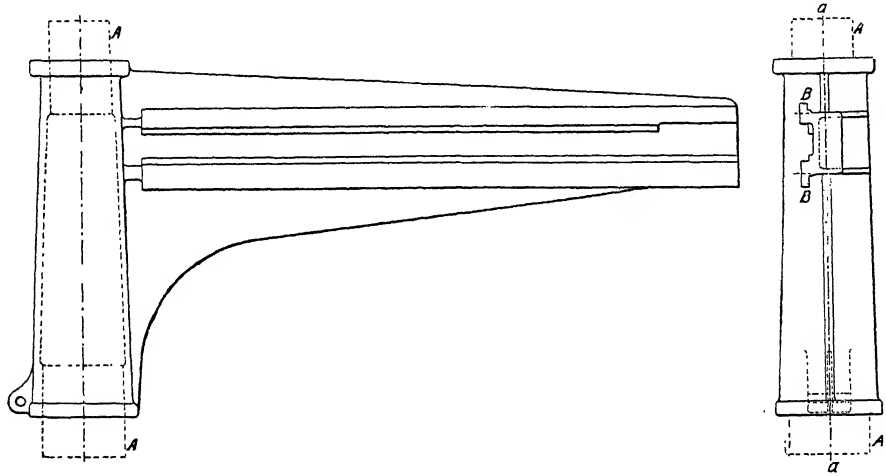


Fig. 14.—Radial Arm of Drilling Machine

aa shows jointing. A, A, Prints. B, B, Loose pieces.

Details of Green-sand Moulds.—Although some details given here concern moulds made in dried sand and loam, others do not, or only in a lesser degree, so that the present section is the most suitable for their consideration.

Provisions Made for the Support of Sand.—Owing to the fragile nature

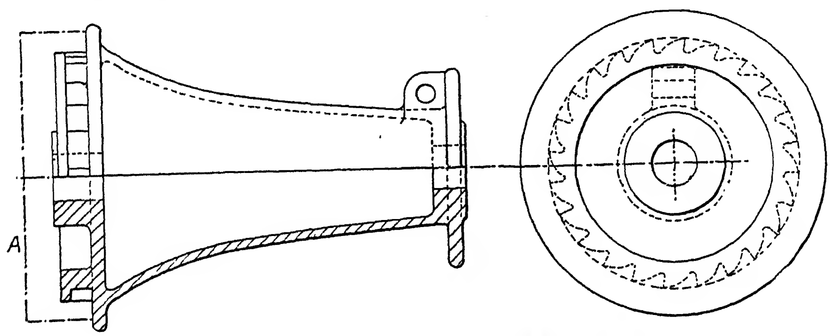


Fig. 15.—Section of Fusee Barrel for Derrick Crane

A, Print for ratchet core.

of green sand, abundant support is required. All boxes, except the smallest, those say of from 12 in. to 15 in. across, are bridged with stays or bars (see figs. 16 and 36), spaced at from 6 in. to 8 in. apart. Those in the bottom box are flat, since the sand there cannot fall out, being supported by the floor on which the box rests. Those in the top are vertical, extending down

to within $\frac{3}{4}$ in. of the joint face in a "plain top", or to within $\frac{3}{4}$ in. of the pattern when the box is made for special work only. In the latter case the bottom bars are shaped similarly, as in pipe and column work. The bars retain the sand by their proximity, and the friction of their rough surfaces, assisted by an application of clay wash before ramming. Middle parts seldom have any bars, but narrow flanges are cast within top and bottom edges to assist in sustaining the sand, and to carry rods laid on them and disposed close to the pattern. Small flasks for brass moulding have internal flanges, and some have their sides recessed to a very obtuse angle to prevent risk of the sand falling out.

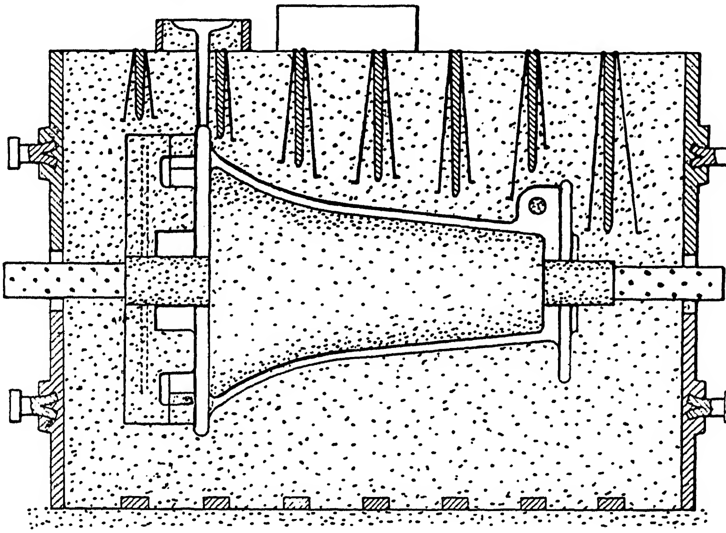


Fig. 16.—A Cored-up Mould for a Fusee Barrel

Lifters, Rods, and Nails.—When deep portions of moulds or recessed pockets of sand extend considerably below the lower edges of the bars, these receive support with "lifters" or "S-hooks" (see fig. 16), suspended from the tops of the bars, and going down into the sand rammed around them. They are bent at both ends, one to rest on the bars, the other to assist in holding the sand. They are wetted with clay water.

When portions of sand extend out horizontally, they would break down by their own weight, or be washed away by the inflowing metal, unless supported with rods in the larger sections, or cut nails (sprigs) in the smaller. In each case the length must be sufficient, when enclosed in the sand, to counterbalance the portion that overhangs. All weak portions of sand have to be treated thus, so that a rather large amount of "sprigging" has to be done in some moulds.

Venting.—With the exception of some small moulds, made with an open self-venting sand, and most loam moulds, venting done with a rod or wire is necessary. The vents are driven from the outside of the moulds close to

the surfaces of the patterns. The air and gas escape directly through the top of the cope. That from the drag is brought out through large horizontal channels driven between the bottom of the box and the sand floor on which it rests. Vents that come into the joint faces are led into shallow gutters cut in those faces, and surrounding the mould, to come out through the box joints. The vents from large bedded-in moulds in the bottom are taken down to a cinder bed, to be discharged through pipes outside. A similar practice is adopted when very large masses of sand occur in closed moulds. Bodies of clinker or coke are introduced. Into these the vents are led. The gases are discharged quietly through these without risk of partial explosion and shock to the mould. Vents from large moulds are generally ignited with a hot skimmer. The amount of venting in moulds varies. Close, loamy sand, and portions that are rammed hard require the maximum amount. Insufficient venting is productive of blow-holes, and of scabbing.

Delivery and Mending-up.—Some rapping is necessary to loosen patterns for delivery. Its severity has to be greater with increase in depth, in the proportion of vertical faces, and in area. The point of the bar is inserted in the pattern, or in a hole in a rapping plate, and the bar is struck with a hammer laterally from all sides. During the early stages of delivery, the top of the pattern is rapped slightly with a wooden mallet to assist its detachment from the sand. The edges of the mould all round adjacent to the pattern are swabbed with water to lessen risk of the sand being torn up. But some fractures, except in the case of semicircular and allied outlines that are most favourable to delivery, almost invariably occur. These have to be repaired by a process of mending-up.

When a mould is very badly damaged, it is better to put the pattern back, and re-ram the parts, but this is not practicable when it is of unwieldly dimensions. Portions of the pattern are sometimes detached for making broken sections good; often supplementary pieces are prepared to avoid such removal. In most instances the moulder mends up with any odds and ends suitable—straight strips, sweeps—or he bends sheet lead to outlines. Nails may be thrust into the broken sections, and swabbed to assist the coherence of the sand, and a stronger sand, skin-dried, will often be useful. In mending-up, it is not easy to preserve correct dimensions and outlines. Often this is of little or no consequence, but it is so when work has to be set in fixtures for machining. This is one of the reasons why machine-moulded castings should then have preference.

Pouring Arrangements.—Many moulds free from faults in the making have produced damaged or waster castings because of improper methods of supplying them with metal. Molten iron, steel, and brass are heavy, and sand is fragile. The ideal method is to bring the metal in, in a position which varies in different classes of moulds, and to let it distribute itself, and rise quietly, instead of rushing and beating against weak sections of sand, against cores, or parts that have to be machined. Moulds of moderate depth are generally poured from the top (figs. 16 and 36), the metal being brought into the thickest portion of the casting, such as a central boss, the

ingate and runner being one. Deep moulds are treated differently. The metal is either led in somewhere down the side, to lessen the height of its fall, or at the bottom, to rise quietly without any cutting action or splash.

The pouring basins for small moulds are of simple cup-shapes, moulded in iron rings set on the top box, through which the metal, skimmed, passes directly into the mould. But when large moulds are poured from a ladle slung in the crane, some little time is spent in tipping and adjusting the spout of the ladle. The first driblets, therefore, are not permitted to fall directly into the mould, but into a deeper depression of the basin to one side of the runner. The metal then being poured into this in a full volume overflows into the runner, slag being kept back by the skimmer. When a mould is filled through several adjacent ingates, they are supplied from a common basin. Long moulds are poured from opposite ends, to avoid the chilling effects of a too-prolonged contact with the cold sand.

No rule can be stated for the cross-sectional areas of runners and ingates. These have to vary with the degree of fluidity of metals and alloys. The only rule is to have them large enough to fill the mould before any chilling effect can occur. Also, the thinner the metal the more numerous must the ingates be made, until for the thinnest a spray of runners is used, fed from a common ingate. In castings of medium thickness, a runner of oblong section, much longer than its thickness, is used. Oblong runners are also better than large round ones for the fettlers, because they are more easily severed, and are less likely to cause a depression in the casting if broken off.

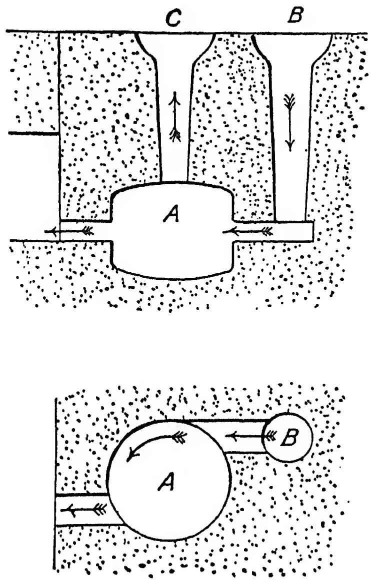


Fig. 17.—Skimming Chamber

A, Chamber. B, Ingate. C, Riser.

Skimming chambers are provided when metal has to be scrupulously clean. Ordinarily metal is cleansed by "dead-melting", and by baying back the scoriæ in the ladle with the skimmer. When small articles have to be machined all over, centrifugal action is enlisted to send the heavier metal to the circumference of the chamber (fig. 17), whence it is directed into the mould, leaving the lighter impurities about the centre, to remain there or to float up into a riser.

Risers and flow-off gates resemble the plain cup-shaped pouring basins, and their functions are (*a*) the relief of excess of pressure and strain on the top part of the mould, and (*b*) the discharging of an excess volume of metal with which dirt and air bubbles might have become entangled. Pouring is therefore continued for a short period after the mould has been filled. The relief of strain is important in the case of moulds having large areas.

The liquid pressure will often cause the top part of a casting to "gather" $\frac{1}{4}$ in. or more in thickness. Risers relieve this strain by providing openings into which the metal, otherwise confined, rises quietly. The risers are closed with a ball of sand or clay during the pouring, and are floated off by the filling of the mould.

The object of "feeding" or "pumping" is to supply additional hot metal to compensate for the shrinkage of heavy masses. It is done through a pouring basin, or a specially made opening and cup. Molten metal is poured in, and a $\frac{1}{4}$-in. or $\frac{3}{8}$-in. rod inserted and pumped up and down until the metal becomes too viscous to permit of further movement.

CHAPTER II

Moulding in Dry Sand

Moulding in dry sand is reserved for some massive castings that are required perfectly sound, and free from minute specks and blow-holes. Its principal applications are to steam and hydraulic cylinders. Only strong mixtures of sand can be dried. This excludes all the green sands, which, however, are frequently baked on the surface—"skin-dried". The porosity of the sand in a dry-sand mould when dried largely takes the place of the venting with the wire done in a green-sand mould. The presence of moisture even in small quantity in a mould imperfectly dried is therefore a source of risk.

Practically all dried-sand moulds are enclosed wholly in boxes, and turned over. They are put bodily into the stove to be dried. Since the sand is very fragile after drying, all moulds are "finned" in the joint faces previously to or immediately following the delivery of the pattern, that is, they are pressed down hard with the trowel for a distance of an inch or two back from the mould boundaries, so that when dried and closed they will not fracture. A slight fin is formed, but this is of no importance. Moulds made in dry sand will bear harder ramming and more swabbing than those of green sand. They are coated with wet blacking, while those of green sand are dusted with plumbago powder.

CHAPTER III

Moulding in Loam

Moulding in loam is essentially an application of the form or profiling principle on a large scale to the making of moulds. The loam mixture used is a strong sand, mixed with horse manure. The mixture, having been rendered plastic with water, and thoroughly mixed in a mill resembling a mortar mill, is swept in this condition with the bevelled edge of a board, which is attached to a vertical bar and rotated. The profile of the mould in vertical section therefore corresponds with the profiled edge of the board, and its diameter is set by the radius of the board, measured from the centre of the bar. The mould has to be dried after sweeping. Large central cores are swept like the moulds, but small cores are rammed in boxes and dried.

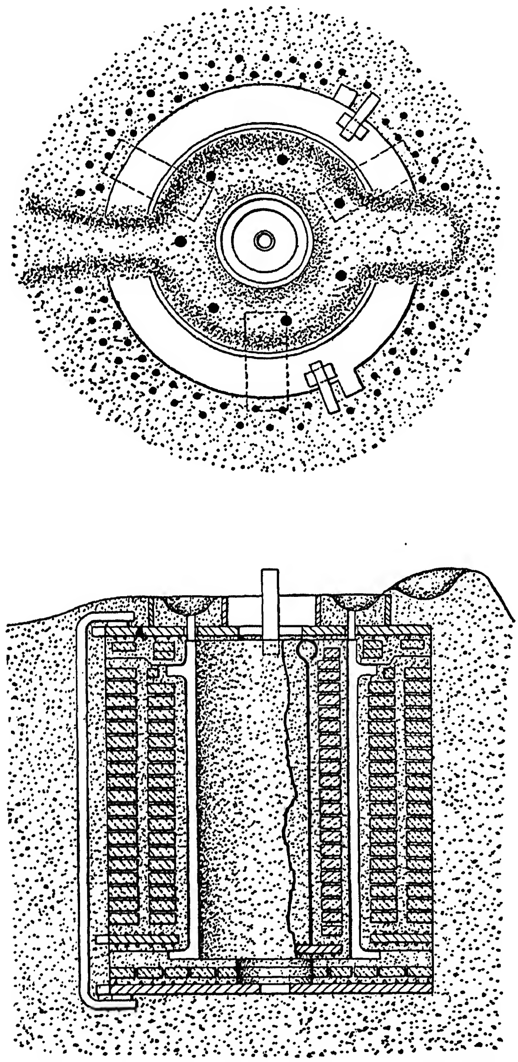


Fig. 18.—A Loam Mould with Central Core in situ, Pouring Basin, Ingates, and Flow-off Gate

Methods of Affording Support to Loam.—Since the treatment of a plastic material, when swept, differs entirely from that of sand rammed within flasks, suitable methods of supporting it have to be provided. All the load of a mould (fig. 18) is carried on massive plates, or rings of cast iron. These are from $2\frac{1}{2}$ in. to 3 in. thick, studded with prods all over the face that receives the loam, and provided with three or four lugs to receive slings for the purpose of lifting the moulds, or, in the case of central cores, with long rods cast in, with eyes. The vertical walls of moulds are swept against tiers of common bricks, built up in a somewhat rough fashion of whole bricks and broken frag-

ments, but always breaking joint. The bricks, dipped in clay wash, are embedded in loam, and finely broken cinders or coke are inserted at intervals in the larger spaces to assist in carrying off the vents. At about every third or fourth course, a layer of headers is laid in to serve as binders. When a mould is very deep, an iron ring, inserted about half-way up, will lessen risk of distortion of the brick walls.

The daubing on of the loam by hand, and its sweeping with the board proceeds with the building up of the bricks. From 1 in. to $1\frac{1}{4}$ in. of space is left between the faces of the bricks and the edge of the board. Coarse loam is used for the greater portion of the thickness, a finely ground mixture for the facing. On the completion of the work, the mould is dried, and blackened with wet blacking, which is afterwards dried. Venting is not required in the same degree as in green-sand moulds, because the loam when dried is, like dry-sand moulds, largely self-venting, and the precaution is taken to occupy all roomy spaces between bricks with fine cinders. But where large masses of loam occur, which often happens in non-symmetrical castings when pattern parts have to be set in by measurement, the vent wire is used freely. After these loose parts are put in position, loam is daubed against them, still supported against brickwork, and they have to be left in situ during the drying of the mould in the stove (figs. 19 and 20). There is risk, unless care is exercised, of these loose pieces becoming shifted during the sweeping, and of their warping in the stove. They must not be varnished, but oiled.

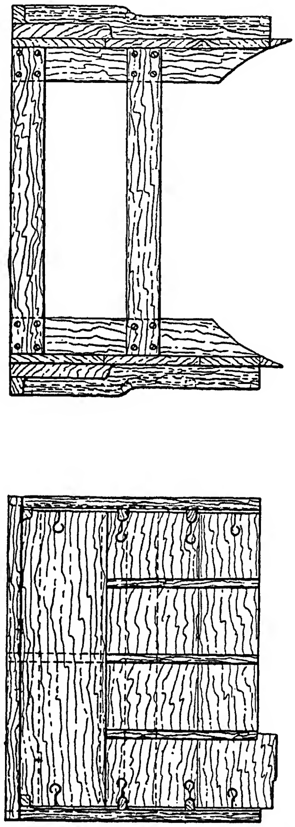


Fig. 19.—Pattern Work for Steam Chest to be embedded against a swept-up Loam Mould

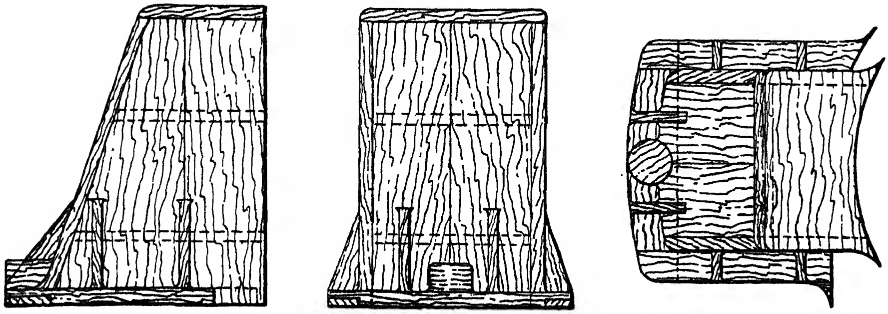


Fig. 20.—Pattern Work for Cylinder Foot to be embedded against a swept-up Loam Mould

The loam that lies in contact with them delivers badly, and has to be made good by mending-up.

Jointing.—Since moulding boxes are not available, jointing can only be done in the actual moulds. The positions of joints are determined by the shapes of moulds. All flanges involve joints and frequently extraneous fittings. The bricks and loam above a joint must be carried with a ring (fig. 18). The cope of a mould is carried on a plate having holes for the ingates, and is turned over, the bricks being retained with rods and plates, though many plain tops only require loam swept directly on their prods. All joints except that of the cope are plane faces, and the cope may be the same when it has no boss or other part that requires exact centring. In this case the joint is provided with a check (fig. 18) that renders it self-centring when lowered into place. The difference between this and other joints is that these can be seen and set while the mould is open. This cannot be done with the cope which closes the mould.

Pouring and Shrinkages.—Loam moulds are poured from the top, usually through a circle of ingates in an annular basin (fig. 18). Moulds must not be closed until shortly before pouring is done, since they absorb moisture. In deep moulds, the pressure is so great that the bricks alone would be liable to yield, and they are therefore rammed in the foundry pit, enclosed with sand walls, or with iron rings. The shrinkages in large moulds would cause fracture of the cooling castings if measures were not taken to enable the mould to yield before them. A layer of loam bricks is used under a top flange, which become crushed under the pressure. Often the labourers break away some of the common bricks under a shrinking flange. Large loam cores which would hinder diametral shrinkage have a perpendicular insertion of loam bricks which yield before the shrinking cylinder. The interior of a large core is filled with cinders to receive and carry off the gases. The gases from the exterior mould are brought out at the top and sides, the latter being formed with large vent channels arranged in a circle outside the mould (fig. 18), made with iron rods rammed in the encircling sand, and withdrawn.

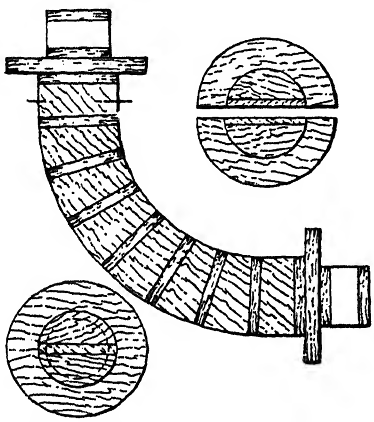


Fig. 21.—Skeleton Pattern of Pipe Bend

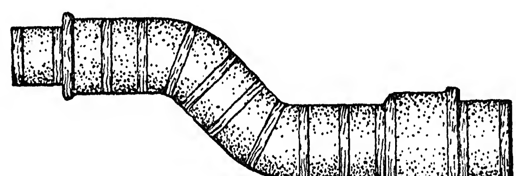


Fig. 22.—Skeleton Pattern of S-pipe with Spaces filled with Sand

Non-symmetrical Work.—This relates to loam moulds taken from skeleton

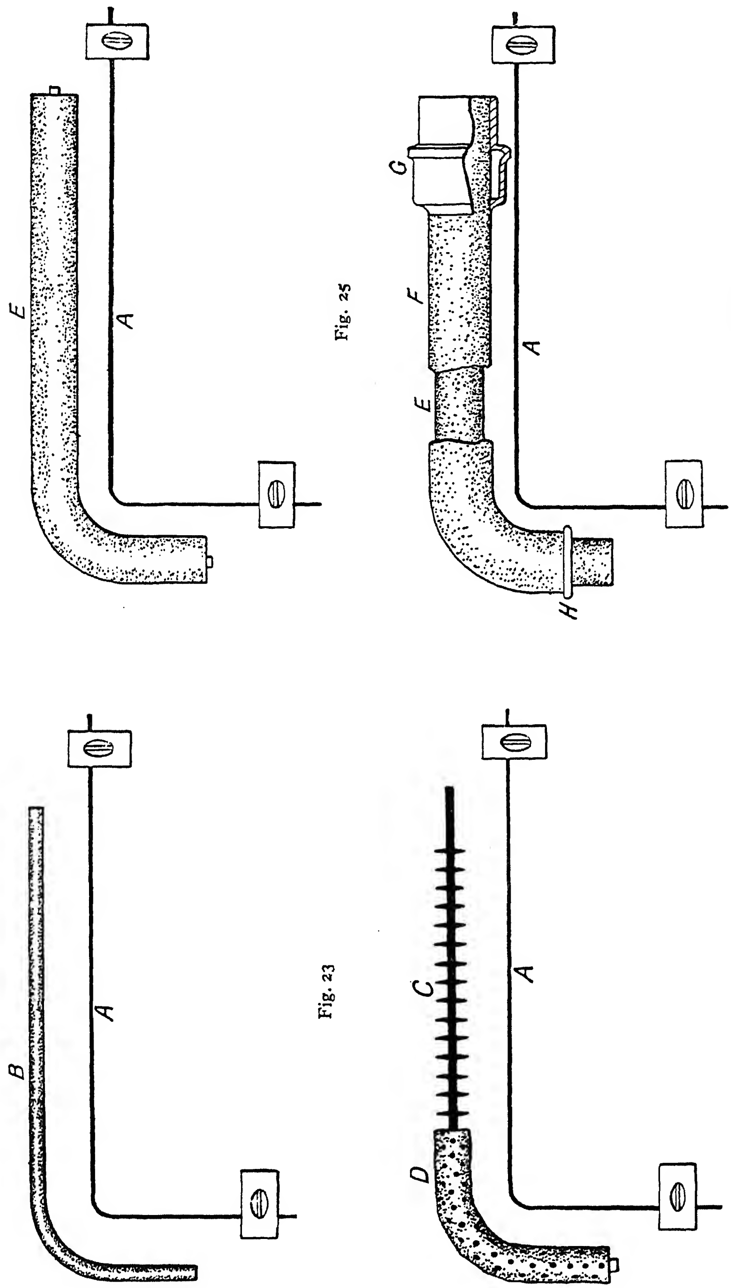


Fig. 23 Fig. 24 Fig. 25 Fig. 26

Strickling a Pipe Bend in Loam

A. Guide iron. B, Form for vent channel. C, Grid. D, Rough coat for core with vents. E, Finished core. F, Pattern "thickness". G, Iron pattern socket. H, Spigot.

patterns. The pattern is broadly similar to the casting, being formed of strips having the same diameter as that of the casting. The spaces between the strips are filled with sand to give a continuous surface, and the core is built within and dried, and the outer mould constructed. This is dried,

and removed in sections, the pattern is unscrewed and taken away, leaving the core to be removed. An advantage of this method over the making of a separate pattern and core box is that the correct thicknesses are ensured. But the real reason for the adoption of the method is economy of timber and pattern-maker's time. It is reserved therefore for the larger castings.

Loam Patterns.—These, swept in loam, are used instead of those made of wood, to be rammed in moulds of green or dry sand. This is a rather large and important section of foundry work, the object being, as in loam moulding, to save the prohibitive cost of complete patterns of wood. It includes symmetrical work, revolved against the profiled edge of a board fixed on the core trestles, and non-symmetrical articles, formed as half patterns with strickles, the longitudinal movements of which are controlled by guide irons, or by the edges of contour plates on which the pattern halves

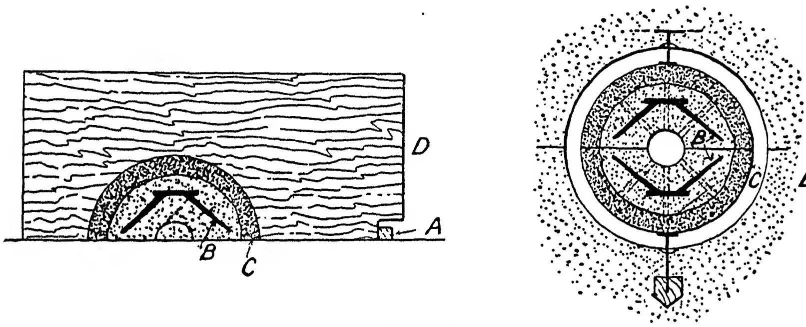


Fig. 27.—Pipe made in Loam

A, Guide iron. B, Core grids. C, Core. D, Strickle. E, Mould with core and its chaplets.

are swept. The longitudinal shapes are determined by the character of the castings required. They may have regular or irregular curves, or curves combined with straight portions. Instead of using loam patterns, it is often cheaper to make a rough skeleton pattern of wood, with outline ribs, fill the spaces with sand, and ram it in the mould. Fig. 21 shows a skeleton pattern for a pipe bend as sent from the pattern-shop, and fig. 22 one for an S-pipe, having the spaces filled with sand.

Figs. 23 to 26 illustrate the making of a pattern, and core for a loam bend. A is the guide iron, set with weights, B is a slender body of loam which forms the vent channel of the core, E, a part of which, D, is seen roughly daubed on the grid C in fig. 24, with its vents, and which is completed in fig. 25. In fig. 26 the pattern "thickness" F, corresponding with the thickness of metal in the casting, has been laid on, and the standard iron pattern socket G and spigot H set, completing the half pattern. After the pattern has been moulded, the thickness is stripped off, leaving the core ready, when blackened, for insertion. In fig. 27 the core strickle, controlled by the guide iron, is seen bridging the core, and the mould is shown to the right, with the core inserted.

CHAPTER IV

Core-making

The foregoing descriptions relative to the making of moulds apply substantially to the preparation of cores. That is, these may be (*a*) rammed in green or preferably in dry sand, (*b*) swept in loam with revolving or with fixed boards, or (*c*) made with strickles. Generally, the same provisions have to be made for cores as for patterns, in the shape of taper, in the employment of loose pieces and prints for inserted cores, and for shrinkages. Taking suitable precautions, there is no casting so intricate that it cannot be produced with the help of cores. As the support of a moulding box is not available, a large amount of detail is associated with the supporting elements around which cores are rammed. These are round rods and wires in the smallest,

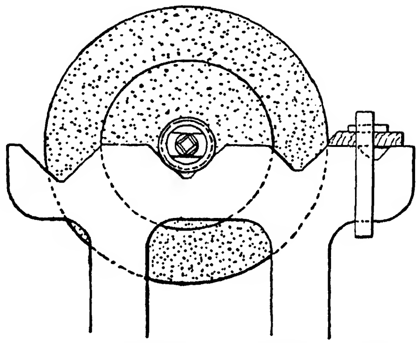


Fig. 28.—A Core being swept against the edge of a Board on Trestles

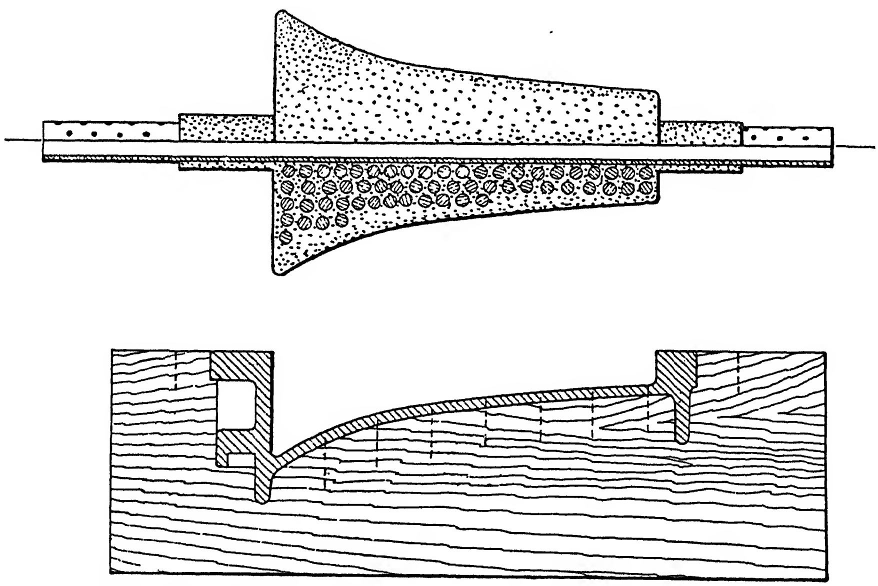


Fig. 29.—Core swept on Bar for Fusee Barrel, fig. 16. The section of the casting is drawn on the board for the information of the moulder

and grids of multifarious forms in those of large dimensions. For loam cores made by rotation against the edge of a board, stiff cylindrical bars

are revolved on trestles (figs. 28 and 29), the latter showing the section of the core inserted in fig. 16, and the casting section on the board. These

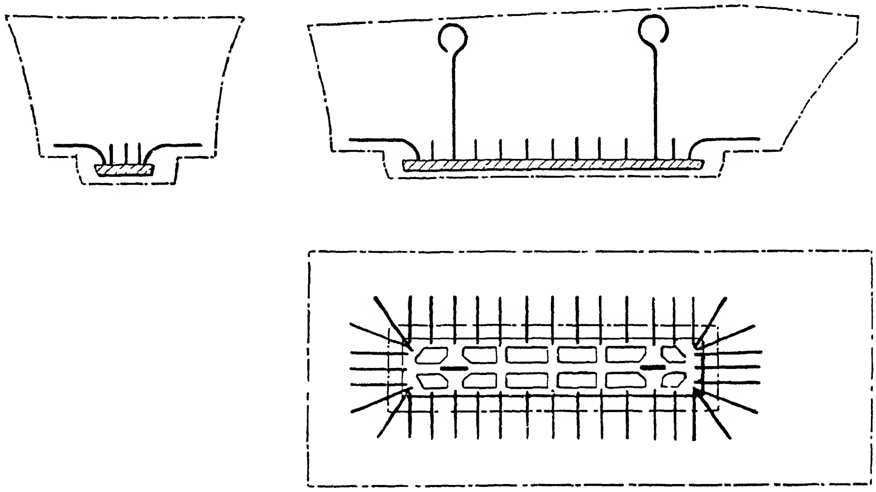


Fig. 30.—A Grid with Rods and Lifting Eyes cast in. The relation of the core rammed on it is indicated by dotted outlines

carry the loam and hay bands, and are perforated for the discharge of the gases generated during pouring. In the absence of a containing flask, provision, in the form of rods with eyes, and of extensions of grids, has to be made for lifting all except the lightest cores.

Cores rammed in boxes are always liable to increase slightly in dimensions, and to " gather " as the saying is. The box sides yield before the pressure of

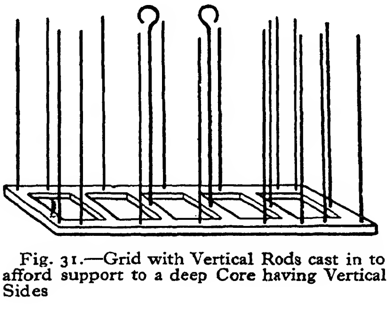


Fig. 31.—Grid with Vertical Rods cast in to afford support to a deep Core having Vertical Sides

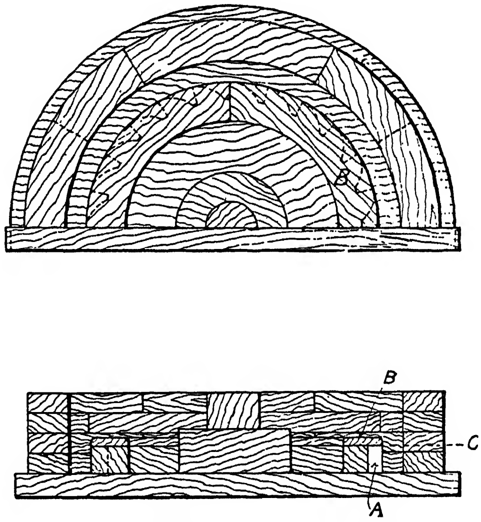


Fig. 32.—Core Box for Ratchet End in fig. 16

A, Ratchet. B, Shrouding. C, Line of joint in core.

ramming, and when removed the core swells a little. This is the reason why so many of the larger cores have to be " rubbed " by the moulder to reduce their dimensions. A careful pattern-maker will counter this by

making the box sides as rigid as possible, and by slightly reducing the interior dimensions. These precautions should always be made in standardized work, and provision made for the taper of core prints in the boxes, to avoid rubbing the taper on the cores. Another reason why cores

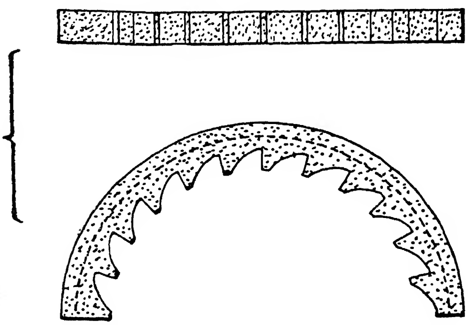


Fig. 33.—The Ratchet Core in fig. 16

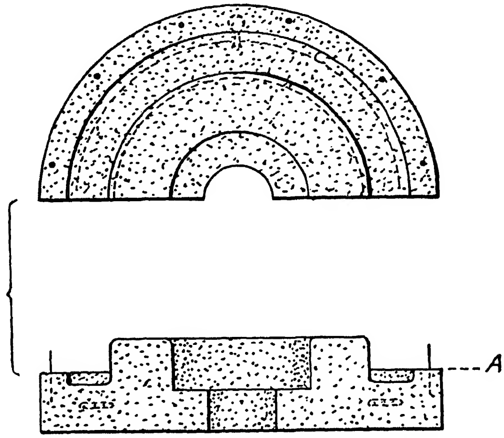


Fig. 34.—End Core without Ratchet in fig. 16

A. Line of joint in core.

should be made slightly below size is that, when dried, they are so hard and rigid that they retard the shrinkage of the casting, so that the interior either comes out too large, or in some cases fracture occurs unless the core is loosened while the casting is cooling.

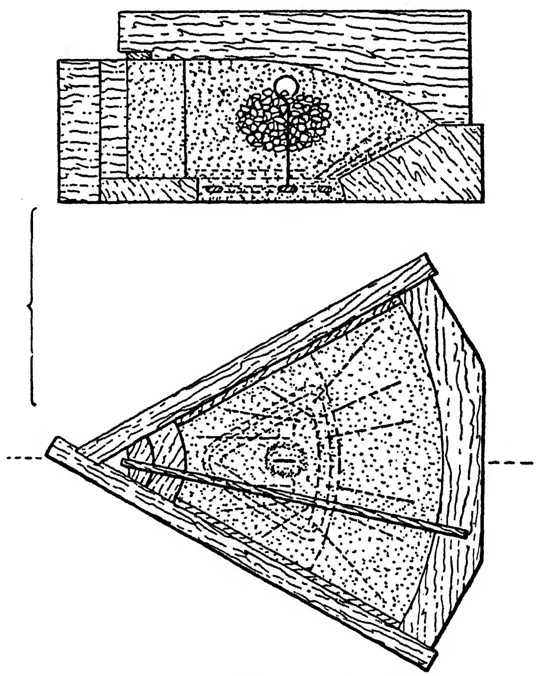


Fig. 35.—Core Box for Bevel Wheel

Details of Core Formation.—Generally this work is done by the core makers, a class of men apart from the moulders. But this is merely a matter of economy, a useful division of tasks, since moulders can prepare their own cores, and do so frequently in the small shops. Referring first to those cores which are rammed in boxes, the work is substantially that of dried sand moulds, with the difference before noted, the employment of an interior supporting skeleton, the "grid", in place of an exterior flask. The first thing, therefore, which has to be decided is the form and dimensions of the grid. This both carries the load of sand, and affords the

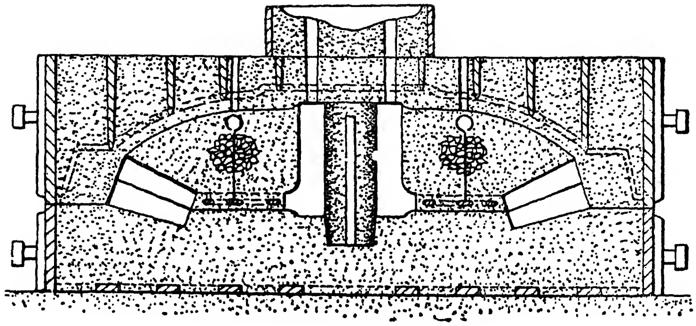


Fig. 36.—Cored Mould for Bevel Wheel

means of lifting it into the stove and mould (figs. 30, 31, 35, and 36). When practicable, the core is rammed in the same position that it has

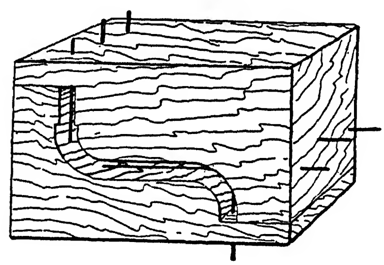


Fig. 37.—Core Box, with Vent Rods

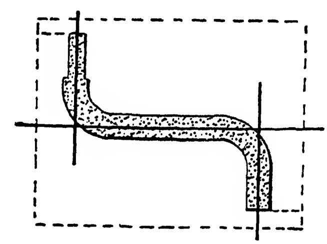


Fig. 39.—Shows Vent Rods in Core

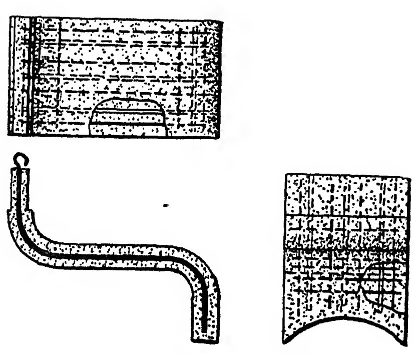


Fig. 38.—Core with Stiffening Rods

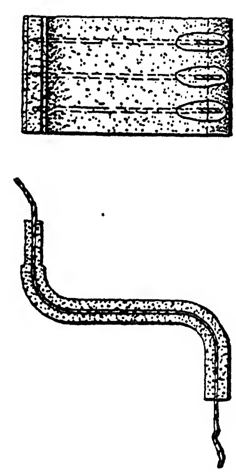


Fig. 40.—Vent Strings in Core

to occupy in the mould, turning it over being generally avoided. Eyes therefore come in the upper part of the core. The outlines of the grids must follow approximately those of the core, so that a suitable grid has to

be made for every core. These are cast in open sand from patterns kept in stock, the moulds being stopped off to any outlines and dimensions required. A large proportion of core grids can only be removed from the interior of their castings by breaking them up and extracting them in fragments, for which reason they are not made of sections stouter than are necessary to sustain the load of sand. And generally in the deeper cores, the cast grid occupies the bottom only,

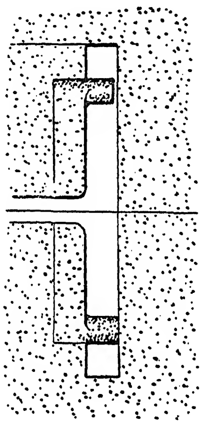


Fig. 41.—Cores inserted in Drop Print Impressions, bottom and top parts

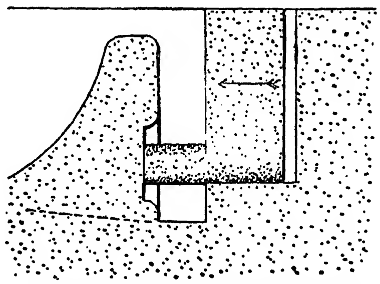


Fig. 42.—Core inserted into Drop Print Impression and moved along into a boss

support for overhanging masses being afforded by wrought-iron rods of from $\frac{1}{4}$ in. to $\frac{3}{8}$ in. diameter cast into the grids (fig. 31). For small weak sections, nails are embedded in the sand as in the similar situations in moulds. Grids for cores therefore assume an infinite variety of forms.

Having the core box set on a level surface of iron, wood, or sand, and the grid prepared, a

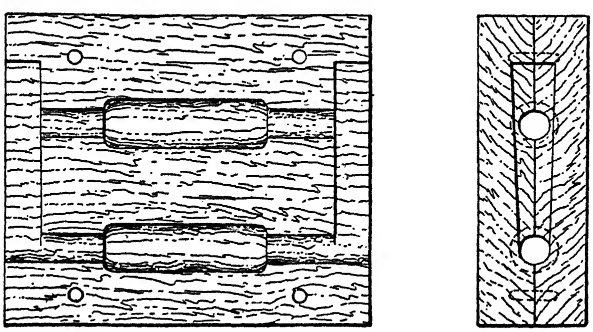


Fig. 43.—Core Box, which includes two cores in drop prints

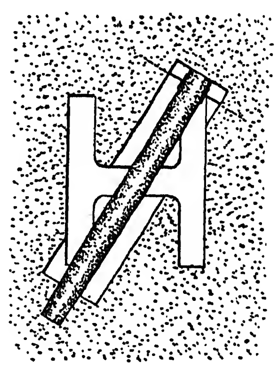


Fig. 44.—Setting a Core diagonally with bottom print only

stratum of core sand is sieved over the bottom, to a depth, say, of about 1 in., and the grid, well swabbed with clay wash, is bedded on it. More sand is sieved or shovelled over the grid, and rammed over the grid and against the sides, using the pegging rammer. Then, in all cores except those which are shallow, a portion of the sand is scooped away from the centre and heaped against the sides, and rammed with additional supplies

until the top of the box is reached. The vent wire is now used freely, being driven from the central open space to the box sides. The interior is next filled with broken cinders or clinkers just lightly consolidated with the rammer, a piece of tube inserted to receive and convey away the vents, and the core is completed with sand rammed over the cinders to the top of the box. The edges are swabbed with water, the box sides detached and removed, leaving the core standing ready to be put into the drying stove.

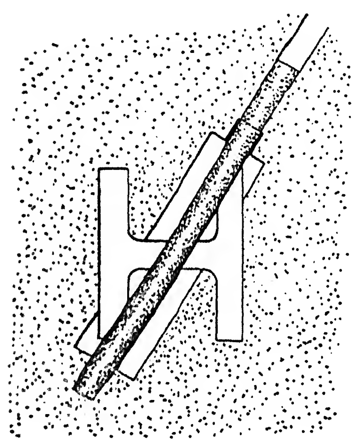


Fig. 45.—Setting a Core diagonally with bottom and top prints

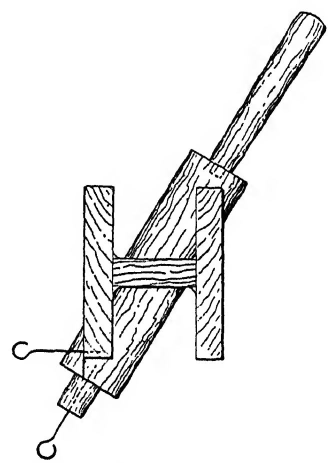


Fig. 46.—Pattern with a long top print for fig. 45

Referring to fig. 15, it will be noticed that the ratchet cast on one end is shrouded or capped, which involves making a joint in the core. The box is shown in fig. 32, the ring core being in halves for insertion in top and bottom moulds, the core for the ratchet in fig. 33, and the remainder in fig. 34.

Fig. 35 shows the core box for a bevel wheel, with the core completed, the grid, and central mass of cinders being indicated, and the strickle that produces the curve corresponding with the edges of the vertical arms. Fig. 36 illustrates the mould, cored and closed for pouring.

Cores that are curved and thin, like those for the passages of cylinders, have to be stiffened with rods, and vented with channels. Fig. 37 shows a core box, ready for ramming, with vent rods inserted; fig. 38 a core with stiffening rods; fig. 39 shows vent rods in a core previous to its removal from the box; and fig. 40 the filing of grooves where the rods cross, for the insertion of core strings, the portion filed being filled after, and the string withdrawn.

Fig. 41 illustrates the fitting of cores in drop print impressions; fig 42, the thrusting of a core along into a boss, the space behind to be filled with sand; fig. 43, the inclusion of two cores made in one box, with drop prints common to both; figs. 44 to 46, two methods of setting round cores diagonally.

CHAPTER V

Moulding Sands

The vast majority of moulds is made in sand mixtures. The methods that lie outside of these are of a special character, as chill casting, casting in permanent moulds, and die-casting, which, though of growing importance, bear but a small proportion to the large volume of work made in sand. This material is of pre-eminent utility because it is easily rammed or moulded into any outline, it is so highly refractory that it is not fused by the temperature of molten metal, it is adhesive enough to retain the shapes imparted to it, is porous enough to permit of the escape of gases generated in the mould by the molten metal, and, being quarried in many districts, its cost is low.

Sand is never used in the crude raw state in which it arrives from the quarries. It is wet, lumpy, non-homogeneous, and has to be subjected to preliminary treatment in machines. And few sands are employed alone without admixture, though some are used thus because of their self-venting properties. The judicious mixing of sands to secure the best results for different classes of moulds is one of the tasks of the foreman, who has generally to work with those kinds that are obtained locally.

Facings.—The essential mixture is the facing sand. This is prepared to line the mould for a thickness of 2 in. to 3 in. next the pattern. Elsewhere the flask is occupied with the " black " or " floor " sand, which occupies the foundry floor to a depth of about a couple of feet, and which consists of the accumulations of years from former moulds. It has lost its original properties by repeated bakings, but when riddled and moistened with water it is used for box-filling, serving as a backing to the facing sands. Broadly, these are grouped as being " weak " or " strong ". The difference is that the first contains a smaller proportion of heavy clayey material than the second, also less coal dust. The function of the latter material is to prevent the occurrence of " sand-burning ". While the infusible silica is the basis of sands, a proportion of alumina is essential to provide the bond of coherence. Oxide of iron is also present, and both these substances are fusible at pouring temperatures. The coal dust lessens risk of resulting roughening of the " skin " of the casting, by forming a film of one of the oxides of carbon between the sand and the casting, a result which is assisted by the plumbago facings dusted or brushed on the moulds. It follows that the larger the proportion of clay present in strong sands, the larger must be the quantity of coal dust. The amount will range from one of coal to six or eight of sand in the strong sands to one in fifteen in the weaker mixtures. Large moulds in which the metal remains hot for a long time require more coal dust than small moulds that cool quickly. The determination of the strength of a mixture for a given mould is one of much importance. Different grades are desirable for different parts of the same mould. Areas subject to great

liquid pressure, as large copes and the bottoms of deep moulds, should be rammed with stronger mixtures than the sides. But venting must be more thorough, or the casting will be "scabbed".

Green, Dry, and Core Sands.—The feature which these have in common is that they are consolidated with the rammer while in a moistened condition. They are never wet, but sufficiently damped to retain a shape imposed when squeezed in the hand. The retention of the form produced during ramming depends partly on the coherence of the sand, but largely on the means by which it is sustained in flasks, and on grids. Green sands cannot be dried, except slightly on the surface, without losing their coherence. Sand, to be dried, must be of a strong clayey character, and be mixed with horse manure, which, by its carbonization during drying, counteracts the close texture of the mould, favouring venting. But the vent wire must be used freely too. Coal dust is also used. Core sand is mixed with clay wash, peasemeal, or beer grounds; and generally, dry sand mixtures are suitable for cores.

Loam Mixtures.—These are made with strong sands, vented with horse manure, with which generally a large proportion of old loam is mixed, the whole being ground in a mill with water, and swept thus while in a pasty, plastic condition, to be dried subsequently. It is used in coarse and fine grades, the first for embedding the bricks in, and for the rough coats, the second, finely sieved, for the final coats.

Chemical and Mechanical Analysis.—During recent years, attempts have been made to grade moulding sands by chemical analysis, supplemented with microscopical examination of the grains. These are helpful when new sands are concerned, but their value is discounted when, as is usually the case, large proportions of old sands are mixed with new. It is important that the percentages of silica and of alumina should be known, and also the quantities of iron oxide, lime, magnesia, and alkalies, which tend to lower the fusing point of a sand, and flux it. Silica, the refractory element, must be present in more than 80 per cent, alumina in from 7 to 10 per cent, the proportions varying for weak and strong mixtures. But it is held that the texture of a sand when passed through sieves of different meshes is of more importance when deciding its suitability for a certain class of work than chemical analysis, and that mechanical testing affords an approximate index of the cohesive character of a sand. Weak sands have fine grains, and least alumina. The strong sands possess coarse grains, and a large proportion of alumina. Castings with smooth skins can be obtained with the use of coarsely grained sands. Fine grains are suitable for dry mixtures, cores, and loam, with a large proportion of alumina.

CHAPTER VI

Castings made in Metallic Moulds

Castings made in metallic moulds are embraced in three groups: (*a*) chill casting, (*b*) die-casting, (*c*) casting in permanent moulds. These have nothing in common beyond the fact that cast iron forms the whole or a portion of the moulds. The conditions which control the pouring of liquid metal into moulds of porous sand and those of iron are so different that the foundries using metallic moulds are entirely separated from the sand foundries.

Chill Casting.—The fact is familiar that the effect of pouring liquid metal in contact with a cold metallic surface is to harden—"chill"—the portion that comes in immediate proximity with it. This is utilized in portions

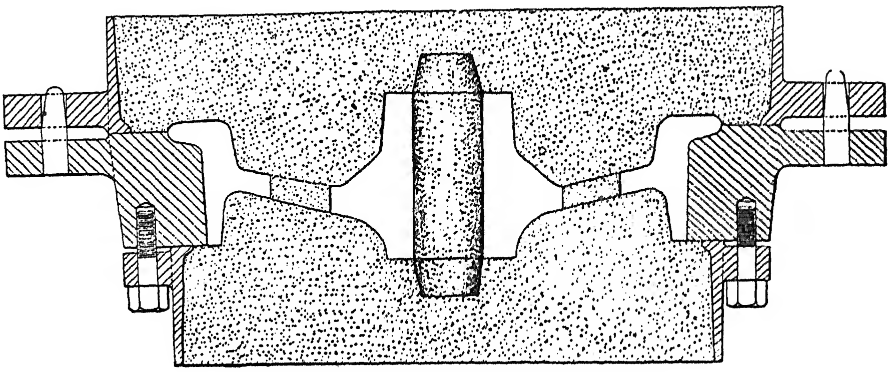


Fig. 47.—Chill Mould for Trolley Wheel

of numerous castings that are subjected to severe wear, as the treads of trolly wheels of all kinds (figs. 47 and 48), in the rolls (fig. 49) for the iron and steel works, for plough points, for mining stamps, stone breakers, balls and rollers used in crushing and grinding mills, the bores of some wheel boxes, &c. In all these cases the mould is of a composite character, being composed of metal over the areas that have to be chilled, and of sand elsewhere.

Composition of the Metal to Chill.—The grey iron used for ordinary castings, in which the carbon is nearly all in the graphitic condition, will not chill beyond a surface hardness of the thickness of stout paper. This is of no value for service. An average thickness is generally required of from ¼ in. to ½ in., extended in massive articles to 1 in. To produce this, it is necessary to select a highly mottled iron, in other words, one in which a considerable proportion of the carbon is in the combined condition, and the total carbon content high. And as silicon tends to throw out carbon in solution into the graphitic state, the proportion of this element must be kept low. Sulphur and phosphorus should be higher than for grey iron castings, since they intensify the chilling effect. Manganese, below one per cent, is beneficial.

It is desirable to take test bars when making mixtures from new brands of pig or selected scrap. Thorough melting is essential, and more coke will have to be used than for the more fluid grey irons. The precautions to be observed in venting, gating, and pouring for sand moulds are required here.

The Design of Moulds to Chill.—Only that portion of the mould which corresponds with the area to be chilled is of cast iron, the remainder being

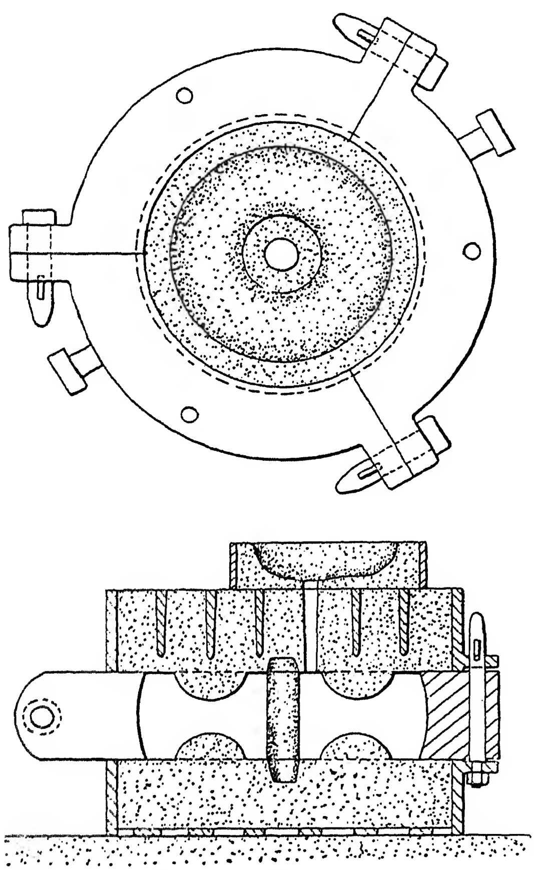


Fig. 48.—Chill Mould for Roller

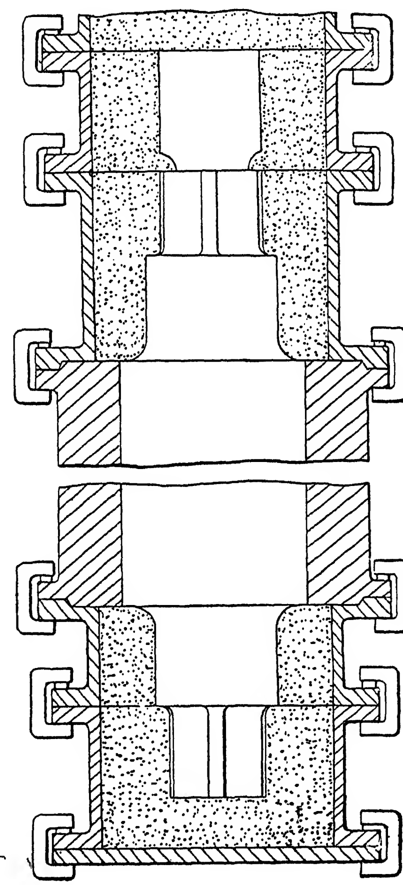


Fig. 49.—Chill Mould for Roll

rammed in green or in dry sand. Success mainly depends on the mass of metal in the chill. It must be large, in order to enable it to carry off the heat from the casting poured, with sufficient rapidity to produce the necessary depth of chill. If this action were delayed too long, what would happen is, that the cementite would have time to break up into iron and graphite, thus: $Fe_3C = 3Fe + C$. Cementite or iron carbide, Fe_3C, is unstable when cooled slowly. The walls of a chill therefore range from 4 in. to 8 in. in thickness, depending on its diameter. The risk attendant on thick walls is that of fracture, since the inner zones, expanding most, are tied by the outer,

and so tend to burst them. The precaution, therefore, is often taken of bonding chills with a wrought-iron ring, shrunk on.

Shrinkages.—When a chill mould is poured, two shrinkages occur, that of the casting inwards, and that of the mould in the contrary direction, so that a space is quickly left between the two of $\frac{1}{8}$ in. or more. Attempts have been made to control and minimize this result, but the practice of dead-melting the metal is usually adopted, that is, allowing it to cool slightly before pouring. Metal thus treated will lie better to the chill than that which is in ebullition.

An effect of the large amount of shrinkage that is consequent on chilling is that the portion cast in sand is weakened if not suitably proportioned. A wheel rim having light arms must almost certainly snap in cooling. Hence these are either made with massive arms, curved lengthwise, or the centres are solid, having a " dished " or corrugated section. Chills do not have a very long life. Though they may not fracture, the surfaces against which the metal makes contact become roughened by the formation of minute cracks, the result of repeated expansions and shrinkages. The metal too deteriorates, approaching the condition of " burnt iron ". A new chill must be cast, and finished by boring. Plumbago is used for facing at the time of casting.

Die-casting.—This is a development, less than a dozen years old, of the linotype castings. Originating with the white metal alloys, those having a basis of lead, tin, or zinc, it now includes those with an aluminium base, and efforts are being made to deal with those of copper. The phenomenal demand for, and the immense supply of these castings is in response to the call for those smaller mechanisms of universal use. These include type-writers, telephones, gas meters, electrical instruments, speedometers, as well as parts of engineers' mechanisms, lubricators, oil cups, bushes, small gear wheels, &c.

Die-castings are made in metal moulds of steel, the liquid alloy being subject to a pressure of 100 lb. per square inch or more, which is maintained until it has set. The result is that the castings do not require machining, being correct to size within a thousandth of an inch, so that they will fit other parts tightly or with sliding allowances and external and internal screw threads will match perfectly. The teeth of gear wheels will mesh. Letters and figures will come out sharply as though engraved. If finely threaded screws or hard contact pieces are required, these can be cast accurately into the softer alloys. Die-casting in steel moulds is used for many small intricate castings which can neither be made economically in sand, nor drop-forged, and many for which the cost of machining would be prohibitive. Though these dies are always expensive, their cost increasing with complexity and the limits of accuracy insisted on, the outlay is relative. A rather complicated die may cost from £50 upwards, but it will endure 50,000 casts of a white-metal alloy, and a slightly smaller number for an aluminium-base alloy. And the advantages and economies just stated are secured by its use, at the cost of a fraction of a penny per casting.

The Die Moulds.—These are made in mild steel for the white metal mixtures, but in one of the alloy steels for those having an aluminium base. No portion of the mould is made in sand. Cores are of steel, and they have to be drawn endwise with a lever from the casting. Sliding undercut parts are similarly treated. Jointing is done when necessary for the removal of the castings. Vent channels are cut. Ingates are severed while the casting is in the mould. Means are provided for the mechanical ejectment of the castings. In the more complicated moulds, where several operating levers are involved, fool-proof methods are included to prevent cores and other sliding pieces from being moved out of their proper sequence. Dies are cleaned after casting with compressed air directed through a hose.

Furnaces.—These are essentially troughs of cast iron in which the alloy is kept molten with a gas flame. The mould is usually carried above the furnace, often on a tilting table. The pressure is put on with a piston in a cylinder immersed in the metal. But many patents have been taken for other methods, with the object of avoiding the blow-holes which are a frequent cause of wasters. Some employ air pressure, others, centrifugal force, with a vacuum, the idea being that blow-holes are due to the entanglement of air, which is doubtful. The case is not analogous to that of green-sand moulding. The cause would appear to be the chilling of the metal against the walls of the mould, forming an unyielding shell before the interior has solidified. The remedy is, to have an ingate large enough to fill the mould rapidly, to bring the metal in where the sections are heaviest, and to inject under adequate pressure.

The Castings and their Alloys.—In the selection of metals to form alloys for die-casting, shrinkage is the predominant factor. For, although casting is done under pressure which is not released until solidification has set in, some shrinkage must occur. Allowance must be made for this in making the dies, or means provided to counteract it. Further, the strength of an alloy to resist elongation by reason of the shrinkage stresses set up during cooling has to be known with some approximation to correctness, because otherwise, by using an unsuitable alloy, fracture may occur in the mould. The case is different from that of ordinary moulds. The cores, being of steel instead of sand, will not yield, sc the metal must have strength to elongate, or it will rupture. And this varies with the proportions of the elements, and with the temperature. This therefore is a matter for experiment. Antimony is used to lessen the amount of shrinkage of alloys. Only a small quantity, from 1 per cent to 2 per cent, is required in the zinc-base alloys, but in the lead-base group it may be alloyed up to 25 per cent.

Classification of Alloys.—Die-casting alloys are grouped as those having low melting-points, below about 800° F., and those that fuse above that temperature. The first are by far the most extensively used, comprising the numerous white metals; the second are the aluminium and copper alloys. Alloys are classified according to their bases, signifying by this the metal which occurs in the largest proportion, and so determines the leading characteristics of the alloy. These are zinc, tin, lead, and aluminium. A very large

selection of alloys is essential because of the multifarious uses to which the castings are applied. In some cases the expansion of an alloy under high temperatures would preclude its use. In many cases steam, oil, alkaline liquids, sea water, and corrosive fluids would disintegrate some alloys, while having no effect on others. Some alloys are too brittle for certain services, others are too soft, while in some, an element will sweat out from the mass. These facts indicate the difficulties which have to be surmounted by the die-caster.

In the zinc-base alloys this metal may be used in a range of from 50 per cent to 80 per cent, tin from 5 per cent to 30 per cent, and copper and aluminium from a mere trace to about 5 per cent. Antimony may be present from 1 per cent to 5 per cent, its function being to reduce shrinkage and impart hardness. Only a small quantity is necessary, since zinc is hard, and does not shrink so much as tin or lead. These alloys melt at from 800° to 850° F. They are affected by alkaline and salt waters. They are the easiest to cast, and the strongest castings are obtained by keeping the tin and copper at, say, from 2 per cent to 5 per cent. Tin is liable to sweat out below the temperature of fusion.

The tin-base alloys contain from 60 per cent to 90 per cent of the metal with from 3 per cent to 7 per cent copper, and about the same proportion of antimony. These alloys are excellent. They are softer than those with a zinc base, and produce castings of good finish, but the price of tin makes them expensive. Babbitt is composed of tin 89 per cent, copper 3·7 per cent, antimony 7·3 per cent with a trace of bismuth. These alloys melt at from 200° to 300° F. lower than those having a zinc base.

In the lead-base alloys the proportions of that metal are high, but their uses are almost confined to the bearing metals. Lead may range from 60 per cent to 90 per cent, tin from 2 per cent to 20 per cent, antimony from 4 per cent to 25 per cent. The alloys lack strength, and are heavy. The tin increases the tenacity and toughness of the lead, while the latter renders the tin more malleable and ductile. The higher the percentage of tin, the better is the surface of the castings, being smoother and brighter. Shrinkage is reduced. Antimony increases fluidity and imparts hardness. The maximum hardness is imparted with 17 per cent of antimony. Up to 13 per cent it expands the lead. Lead will not alloy with zinc, because segregation occurs during cooling.

When aluminium-base alloys were required for some parts of machine-guns, pistols, grenades, binoculars, &c., difficulties were encountered because of the higher melting-point. The temperature of any alloy must not be higher than would prevent it being melted in an iron pot. Aluminium exerts a solvent effect on iron, and a small percentage is found in the castings. An excess over 3 per cent renders the aluminium alloy useless, causing it to become viscous by the raising of the melting-point. A standard mixture is, aluminium 92 per cent, copper 8 per cent. Small quantities of zinc, nickel, and manganese may be included.

Attempts to die-cast brass and bronze have not been crowned with

commercial success. Both the temperature of pouring and the coefficient of expansion are high. With the increased shrinkage the dies are strained badly, and castings crack. The cost in any case is prohibitive. To produce at a profit, the life of a die should be equal to that of 10,000 casts. It has not been found possible to exceed 1000 in the brasses. To pour iron would also destroy these moulds. Yet under different conditions this is done, as described in the next section.

Permanent Moulds.—These are made of cast iron, and iron castings are produced in them. The advantages gained are: (*a*) the saving of time otherwise spent in making a sand mould for every cast; (*b*) the more rapid removal of the castings from the moulds when set. The development, almost wholly confined at present to the United States, is a remarkable one. Its applications are chiefly to pipes required in large numbers, the cores for which are also made in iron. The same grades of iron may be used for castings made in permanent moulds as for those in sand, but iron that would not give satisfactory results in the latter will do so in the first named. Also, harder or softer castings can be obtained from the same metal, depending on the time during which they are permitted to remain in the moulds. A surface chill can be imparted, or the casting may be soft throughout. In any case, cored castings must be removed before they shrink tightly on their cores, otherwise they must be broken up.

The mass of metal in a permanent mould must be large, because a thin-walled mould would become heated so quickly that a rapid succession of castings could not be produced. For castings of 15 lb. weight and upwards, the mould should be of about seventy times the weight of the casting. Castings are removed soon after the outside has set. This will usually occur in from six to ten seconds, but the time will depend a great deal on the weight, the degree of hardness, &c., required. That this can be varied, though using metal of the same chemical composition, is one of the valuable features of these moulds. If a casting is allowed to remain long in contact with its mould, it becomes chilled, a large proportion of the carbon remaining in solution, in the combined form; but if the casting is removed at a bright yellow colour while the interior is still viscous, the exterior will become annealed, and the casting will be soft, the carbon passing mostly into the graphitic state.

It has been proved that iron which is unsuitable for sand casting is excellent for permanent mould work. An iron with a percentage of phosphorus as high as 1·5 per cent, and of sulphur 0·1 per cent, and silicon 2·5 per cent, is as strong as one with smaller proportions. The explanation is, that these remain in normal solution, not having time to separate out.

Permanent mould work has its limitations, due to the fact that iron cores, which must be drawn out endwise, are used. This limits the forms of pipes to those with straight or regularly curved cores. The same hindrance occurs in die-casting. As the castings have to be removed quickly and the moulds are massive, a good deal of mechanism is necessary for rapid and easy handling. In general, from one to two castings are poured and removed

per minute. Chilled car wheels, gear wheels, projectiles, and pipes are the principal articles made in these moulds.

CHAPTER VII

Casting the Metals and Alloys

Although the principles and the general methods of making all sand moulds are similar, yet some details have to be varied with the character of the metal or alloy used. These are so important that the work of the different foundries is carried out by different sets of men who have become specialists. Each of these departments would admit of extended treatment, but the leading facts only can be stated here.

The Iron Foundry.—This, which embraces the largest proportion of cast work, is in a sense the standard to which the practice of the other departments is referred, and with which they are contrasted. The shrinkage of iron is moderate, averaging $\frac{1}{8}$ in. in 15 in. The metal is poured mostly into moulds made of green sand, the ingates and runners of which need not be very large, since the metal flows freely, appearing when thoroughly melted nearly as liquid as water. The thinnest pipes and plates can be poured, no trouble arises from the segregation of the elements, and, generally, the conditions under which the work of the iron foundry is performed are satisfactory. The pouring of moulds has to be modified with the grade of iron used. The grey irons, with say 3 per cent of graphitic carbon, remain fluid longer than the mottled grades with about half the carbon in the combined state, and therefore the runners for these have to be dimensioned to fill the mould more rapidly. Another fact is, that the effects of shrinkage are more severe, with liabilities to fracture if shrinkage is hindered.

The Steel Foundry.—The difficulties of the steel founder are those consequent on the high temperature of casting, and the large amount of shrinkage. While the temperature of molten grey iron is about 2250° F., that of steel is about 2800° F. As the melting-point of silica sand is in the neighbourhood of 3200° F., partial fusion of the mould is liable to occur. This is the reason of the rough skin seen on so many steel castings. Hence these are seldom made in green sand, but in dried moulds with a sand mixture high in silica. Only new sand which has not been damaged by heat is used for facings. The chief trouble has always been the shrinkage. This, which amounts to about $\frac{3}{16}$ in. per foot, coupled with the high temperature of pouring, inevitably produces cracks, warps, hollow places, and fractures in castings that are badly proportioned. Patterns designed for the iron founder cannot, as a rule, be used for steel. Runners have to be much larger, feeding heads and risers are necessary, large fillets are inserted to strengthen adjacent parts, and thin sections must not be tied. In some cases these precautionary provisions will add from 50 per cent to 100 per cent to the weight of the

casting required. And even then the conditions of internal strain are so severe that prolonged annealing of the castings is necessary for the sole purpose of relieving these strains, and lessening the hardness of the metal.

Malleable Cast Iron.—This is a white iron, having the whole of its carbon in the combined state. It is poured into sand moulds, and annealed subsequently in ovens for about sixty hours. This changes the carbon into the graphitic state, rendering the castings soft and extremely ductile. White iron is necessary, because a grey iron would produce spongy castings after annealing. The amount of combined carbon must never be lower than 2·75 per cent. As the white irons, which are viscous when poured, are used, the runners have to be large. The shrinkage allowance is also greater than that for grey iron, and generally precautions similar to those when making steel castings have to be taken, in the form of large shrinkage heads, and the provision of fillets.

The Brasses and Bronzes.—In all these alloys the shrinkage is large, being about $\frac{1}{8}$ in. in 10 in. The metal is not so fluid as grey cast iron, and it sets very quickly. Large runners and large shrinkage heads are therefore necessary, not with a view to prevent fracture, which rarely occurs, but to avoid " draws " and hollow places in the more massive sections. Feeding is necessary in almost all moulds, even more so than in iron, because the shrinkage is greater. The metal in the pouring cup chills quickly, so that fresh metal must be supplied if the mass of the casting is large. Special care must be taken in making the dispositions of the runners. These must be brought into the heavier sections. It is well in deep castings to pour from the bottom. A very large volume of brass work is made with odd sides, or is alternatively plated. In each case numerous small patterns, which may be like or dissimilar, numbering, say, from half a dozen to twenty, are moulded in one flask, and poured from a common ingate. In these cases the runners must be of sufficient area to fill the moulds farthest from the ingate before the metal has had time to congeal, and little or no feeding can be done. Both green and dry sands are used for moulds, the first, as with iron castings, predominating. Generally, the moulds should be rammed harder than those for iron, and well vented.

Aluminium and its alloys are usually poured into moulds of green sand. The shrinkage of the metal is about double that of brass, and large runners are required. The melting-point is rather low, being about 1160° F. The metal must be poured quickly, as it sets rapidly. The pouring basins are large, to act as head metal. Metal rods are frequently inserted in moulds to hasten the cooling of the thicker parts of castings. The alloys of aluminium are numerous. The chief elements employed are copper, zinc, manganese, and magnesium. Moulds of green sand are used, rammed more loosely than those for iron or brass, to prevent shrinkage cracks. The sand may be finer than that for brass, as relatively little gas is given off, and it need not be very refractory. The moulds can be dusted with black lead or French chalk. Green sand cores are desirable, but if dried, they must not be too hard, or they will check shrinkage.

CHAPTER VIII

The Effects of Shrinkage in Castings

All the metals and alloys in common use shrink in cooling from the molten state. Although the amount per foot of length may not appear large, the fact is responsible for the deformation, the lack of homogeneity, the weakness and the fracture of a very large proportion of the " wasters " made. The evils arise from the different rates of cooling in large and light adjacent masses, the very small capacity of cast metal for elongation, and the method of its crystallization. The weakness of cast metals in tension, and their very small percentage of elongation before fracture, when compared with the similar physical properties of forged and rolled materials, are the causes of these results.

The Case of Unequal Adjacent Masses.—Many designs that emanate from the drawing office have to be modified to suit the foundryman's point of

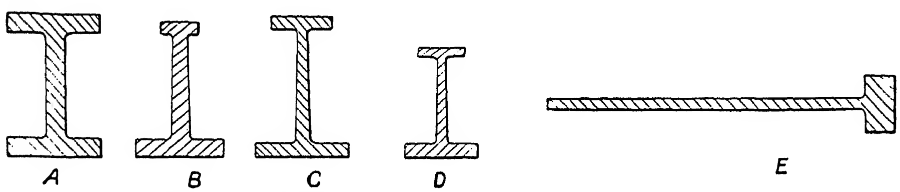


Fig. 50.—Illustrates the Camber of Castings produced by unequal Shrinkage

view. Regarded from his aspect, the ideal casting is one in which thicknesses are approximately equal, with the result that all portions cool and shrink simultaneously. The more intricate the casting and the larger the amount of coring done, the greater is the need for preserving uniformity of sections. Familiar examples are those of steam and motor cylinders, in which the percentage of wasters is often rather large. In these and other castings cores are frequently inserted, or prolonged solely to avoid the occurrence of masses of metal in corners and angles.

But in many designs of machine and structural parts it is not practicable to avoid great disparities in the masses of metal in parts that are contiguous. The moulder then minimizes the evil results, first by " feeding " fresh, hot metal into heavy masses, to prevent the formation of " draws "—hollow places—due to internal shrinkage, and second, by uncovering the massive section, exposing it to the air, in order to cause it to cool within about the same period as the thinner portions adjacent. A great deal of this is done in the case of central bosses for bedplates and heavy pulleys.

Curving, Camber.—Distortion without weakening or fracture is a common result of unequal shrinkage. It is particularly troublesome in long and flimsy castings, as bedplates, gutterings, and similar objects in which there is an excess of metal, not necessarily large, on one side. The casting in cooling becomes permanently concave on that side. In the group of figures,

fig. 50, the section at A being symmetrical will be straight when cold. B, C, and D will become concave along the wider flanges, but in different degrees, C less than B and D, because its top flange is wider. E, where the flange is very wide, will not curve. A wide web resists the effect of flange shrinkage because it is rigid, and it acts as a carrier of heat to the shrinking smaller flange, delaying its setting. The gutter sections in the next group, fig. 51, will all become concave on the solid sides. While A and B will have a curve in one direction, C will be curved both on the bottom and the vertical side. The difficulty which confronts moulder and pattern-maker is how to counteract the effects of shrinkage in unequal sections. No possible rule can be stated, and experience of similar classes of work is the only guide. The greater the disproportion, the more flimsy the casting; and the greater its length, the larger will be the departure from lineal accuracy. A moulder will sometimes uncover a casting or a portion of the same while at a red heat, to hasten the cooling, and so prevent curving. But that is not always practicable, nor is it a sure method. Generally, the pattern-maker imparts camber to the pattern in the opposite direction from that which the casting would assume. Uncertainty, when work is repetitive, is avoided by making one trial casting, noting its amount of camber, and altering the pattern accordingly.

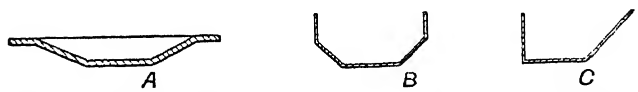


Fig. 51.—Illustrates the Camber of Castings produced by unequal Shrinkage

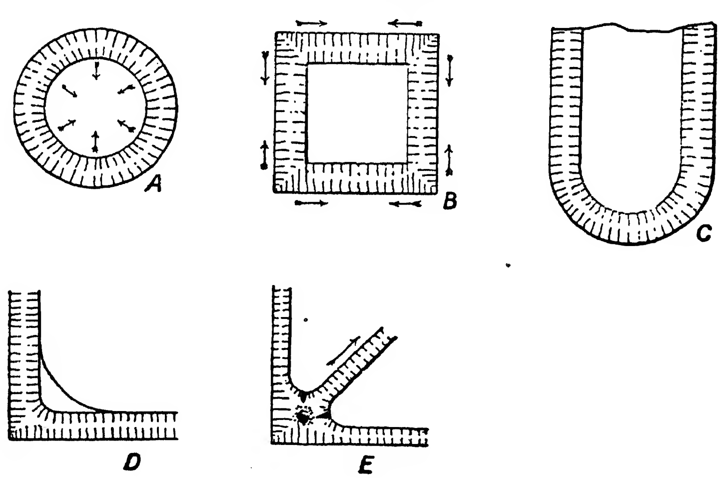


Fig. 52.—Crystallization in Cooling

Crystallization.—The needle-like crystals of cast metals arrange themselves normally in relation to the surfaces of the mould. In fig. 52 the strongest form is shown at A, and the weakest at B. The cylinder at C, terminated with a semi-sphere, is much stronger than one terminated with a flat end. These are commonplace axioms, but they have infinite applica-

tions in all castings made. If the pattern-maker does not put a radius, the " hollow " or " fillet " in a keen angle, the moulder rubs one, as at D, thus altering the weak crystallization of B to that shown. Additional strength is afforded by the bracket at D, common in flanged structures, and which steel makers often insert when not done in the pattern, to prevent cracking of the casting. It is better to fit a bracket as shown at intervals, than to make the fillet very large, because the result might be a " draw " (a cavity in the casting) due to internal shrinkage, such as is seen at E, where three ribs meet with large fillets. This would be prevented, and the casting be stronger if the radii were smaller, which, while favouring suitable crystallization, would reduce the mass of metal in the corner.

Some Common Precautions.—Castings, apparently sound, not infrequently fracture during machining or subsequently. This is because they are in a condition of internal tensile stress, dangerously equal to that of the ultimate strength of the metal. Inspectors test roughly for this condition with hammer blows. Hard sand cores and portions of dried moulds interfere with shrinkage, and a careful moulder will break these up as soon as the metal has congealed. At the best the shrinkage is only lessened, but this in large castings may be sufficient to counteract the allowance for tooling. Bars in flasks adjacent to flanges (fig. 53) will check shrinkage, requiring the breaking away of the intervening sand. Pulley arms are commonly curved, because they will accommodate themselves to the pull of a shrinking boss instead of fracturing. Pulleys with wrought-iron arms must have the boss cast after the rim has become nearly cold. Large runners and risers will interfere with shrinkage, and the moulder often knocks these off so soon as the mould is full.

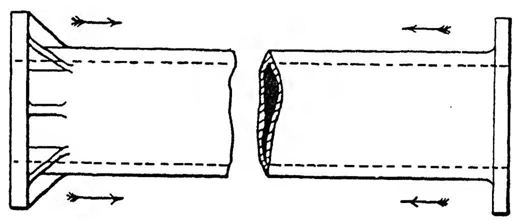


Fig. 53.—Illustrates Shrinkage of Flanges

Right hand, Flange and weak. Left hand, Flange reinforced with brackets.

CHAPTER IX

The Furnaces

The furnaces include several types with many variations: for melting iron, steel, the brasses and bronzes, and malleable cast iron. A large amount of plant and machinery is associated with the operation of each, on which greatly depend not only the economies of working, but the soundness and strength of the castings produced.

The Cupolas.—With many differences in details, the essentials of a

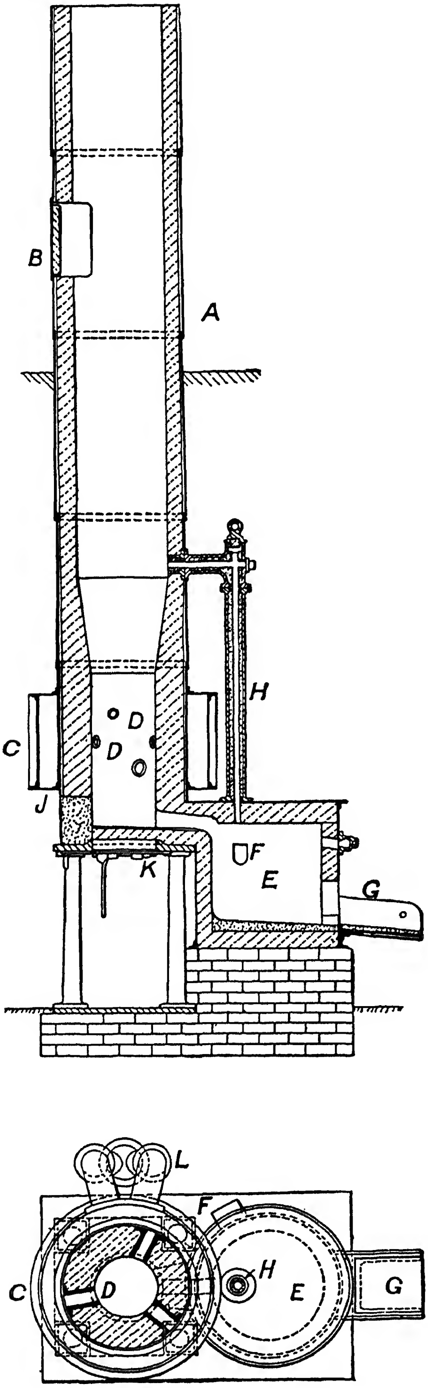


Fig. 54.—The "Thwaites" Cupola

A, Shaft. B, Brick-lined charging door. C, Air-belt. D, Tuyeres. E, Receiver. F, Slag hole. G, Tapping spout. H, Hot-air pipe to receiver. J, Fettling hole. K, Drop bottom. L, Blast pipes.

cupola furnace for melting iron are these (figs. 54 to 57). A tall cylindrical shell, built of wrought-iron or steel plates, lined with fire-brick, daubed with fire-clay for each cast; a charging door near the top; an air-belt encircling the shell at a height of a few feet from the bottom, whence blast under pressure is directed through tuyere openings to iron and coke supported on a deep bed charge of coke. The furnace stands on columns, and has a hinged bottom to permit of the dropping out of the residuary coke, metal, and slag at the termination of the day's cast. Peep holes with mica windows are fitted opposite the tuyere holes through which the furnacemen observe the progress of the melting, and openings are furnished for the removal of the slag, and the tapping of the metal. Many cupolas include a receiver, a circular vessel into which the iron, passing down through the bed charge of coke, trickles and collects, remaining perfectly liquid until it has to be tapped out for pouring. The internal diameters of cupolas range from about 18 in. to 6 ft.; the first will melt about $\frac{3}{4}$ ton per hour, the last, about 12 tons. These are extremes, the first being of value chiefly for occasional light casts, and for making tests of metal, the last being too large for general service, for which internal diameters of from 3 ft. to 4 ft. are preferable.

A cupola is worked as follows: after re-lining the interior with fire-clay each morning, the bed charge of coke is laid in, extending to from 18 in. to 20 in. above the tuyeres. Over this successive layers of pig or scrap, lime-stone, and coke are placed, there being three or four repetitions in this order until the charging door is reached. The fire is lit, and the interior warmed before the blast is put on. In about

fifteen minutes the metal begins to run down. As the charges sink, successive additions are made in the order named. Melting is facilitated by breaking the pig and scrap into small pieces. As fusion is confined to the area immediately above the tuyeres, extending therefrom to a height of about 30 in., metal of different grades, harder and softer, can be charged in the same cupola at the same time if separated with charges of coke. The metal accumulates in the bed charge, and must be tapped before it rises to the tuyere holes.

The Melting Ratio.—Most of the modifications that have been made in cupola design have for their object an increased melting ratio, which is accomplished by supplying enough oxygen in the right place to secure the nearest approximation possible to complete combustion. If a ton of iron is melted with from 2 to 3 cwt. of coke, that represents good average practice. To use less than 2 cwt. of coke is exceptional. This is only possible in lengthy fusions, using: (1) clean iron that throws out little slag; (2) good furnace coke; (3) a deep bed charge; (4) suitable proportioning of fuel and iron; (5) an adequate supply of blast at proper pressure and volume, with variations made when necessary as the melting proceeds.

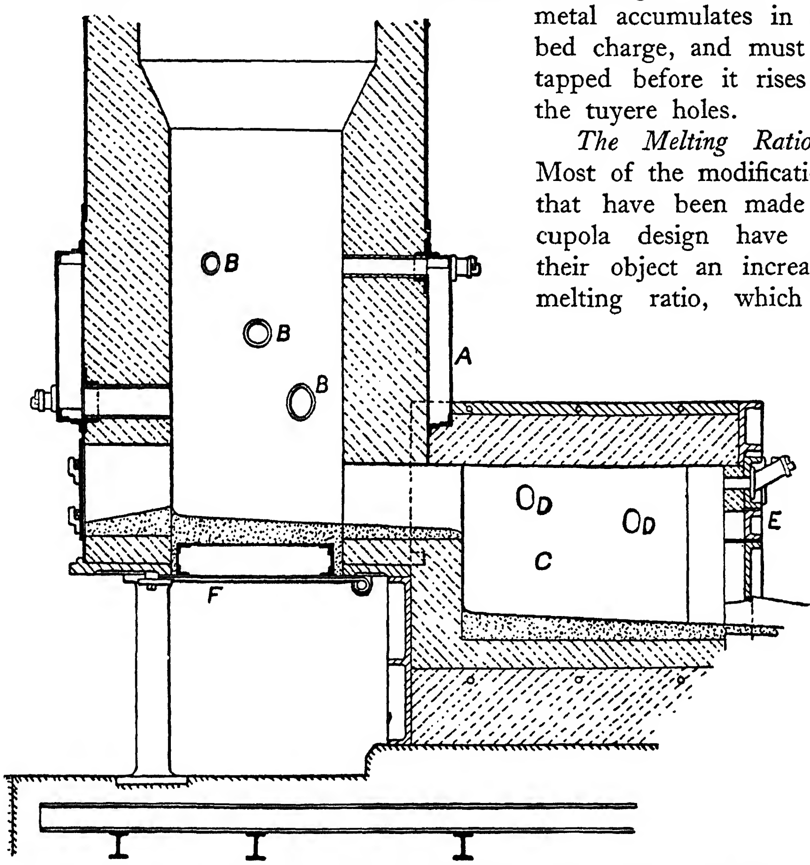


Fig 55.—Cupola, with Air-belt A and three rows of Tuyeres B arranged spirally. C, Receiver. D, Slag holes. E, Tapping hole. F, Drop bottom.

Since the supply of oxygen in the right locality is the master key to economical melting, this explains the very numerous variations that have

been made in the arrangements of tuyeres. Briefly, these usually consist of upper and lower rows, receiving the air from the belt, and discharging it through openings equally spaced round the circle. This disposition has taken the place of the older method of bringing in blast through pipes into two openings on opposite sides, which, with the low cupolas then common, permitted a large proportion of the gases generated from the fuel to pass

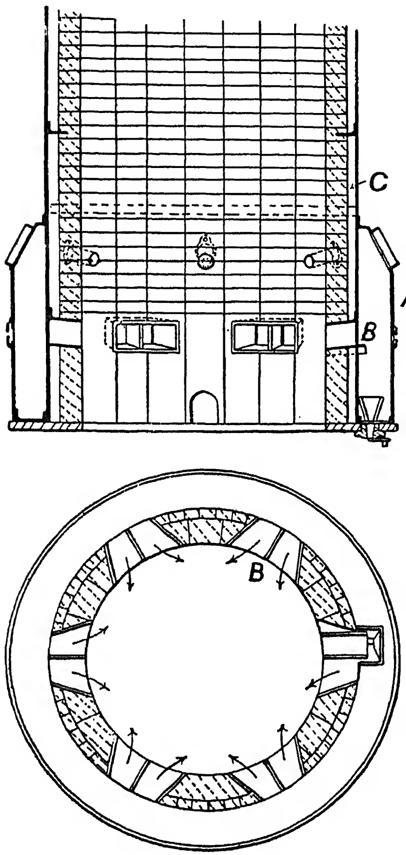


Fig. 56.—The "Colliau" Cupola

A, Air-belt. B, Flaring tuyeres. C, Non-conducting space filled with sand.

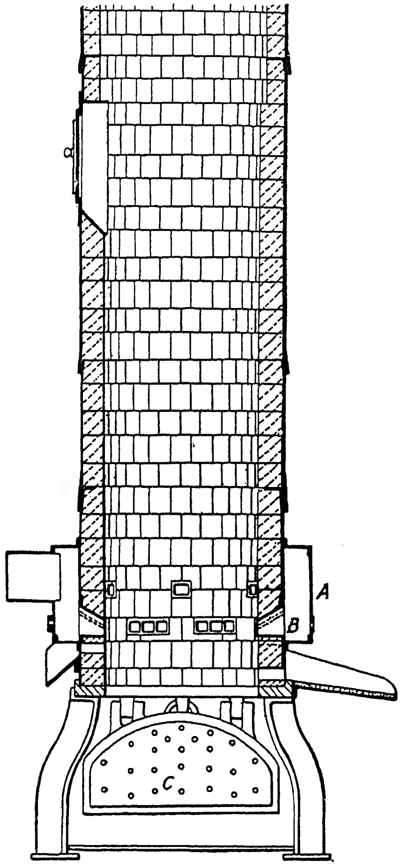


Fig. 57.—"Newten" Cupola

A, Air-belt. B, Differential tuyeres. C, Drop bottom

away out at the charging door and at the top, unconsumed within the furnace. When carbon is burned, 14,647 B.Th.U. are given out per pound, the carbon uniting with the oxygen to form carbon dioxide, CO_2. This is called complete combustion. If, however, the combustion is incomplete, due to an insufficient supply of oxygen, carbonic oxide, CO, is formed, and if this is allowed to escape, about two-thirds of the heat is wasted, since the burning of carbon to CO evolves only 4415 B.Th.U. The object of the upper row, or rows, of tuyeres which have assumed bizarre forms in some designs is to

supply the additional oxygen to the CO formed lower down by the combustion of the coke. The same result is accomplished by additional height, since a more prolonged contact of the carbonic oxide with the heated blast is assured. For it must be remembered that the blast is cold when it enters the furnace, and its oxygen must be highly heated before it will enter into combination. Much heat is wasted in warming the upper charges, and the large proportion of inert nitrogen in the blast.

Blowers and Fans.—The first named (fig. 58) are used now more often than the second, because the action is positive, the air being driven out under definite pressure. Good results are also obtained from fans if they are selected and used with judgment, but generally they are more suitable for the lower pressures, say not exceeding 8 oz. per square inch. The fan has to revolve at a very high rate of speed; that of the blower is moderate, and the pressure and volume are under better control. The speed of a fan cannot be increased beyond that for which it is rated without absorbing power that increases with the cube of the number of revolutions. Hence one of large diameter should be selected to allow for contingencies. In either case the supply pipes must be large, free from quick bends, and of minimum length possible from the machine to the cupola. A blast gauge is necessary as a check upon the working. It reads to 2 lb. pressure, and is subdivided into ounces. It is necessary to regulate the blast at different stages of melting. This is done by varying the amount of opening of the blast gate. At the normal pressure of from $\frac{3}{4}$ lb. to 1 lb. per square inch, the blast must supply from 30,000 to 40,000 cu. ft. per ton of iron melted per hour. The makers of blowers and fans give the capacities for different sizes. From $3\frac{1}{2}$ to 4 b.h.p. per ton melted per hour are required.

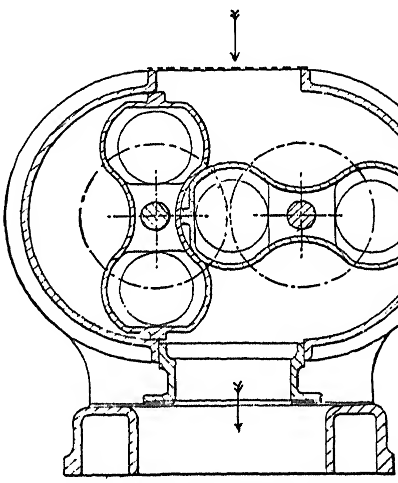


Fig. 58.—Section across Pressure Blower

Ladles.—These, up to about 3 cwt. capacity, are carried by hand, by one, two, or three men, hence termed "hand shank ladles". Larger sizes are slung in the cranes, or run on carriages on rail tracks. All are tipped when pouring. Fig. 59 shows a common form, where the tipping is done through bevel and worm gears. It is effected similarly in fig. 60. This type can be run on tracks, or lifted in a crane. Both have two pouring lips, to be tipped to either side. The bodies of ladles are formed of pressed steel plates, stiffened with belts. Capacities are reckoned inside the fire-clay lining with which they are daubed each morning. A cubic foot of ladle capacity is the equivalent of 3 cwt. of iron.

Pig Breakers.—A great deal of pig is still broken up with the sledge. Fig. 61 shows a machine used for the purpose. The pressure is not direct, but operates through a lever arm that is pushed up by a hydraulic ram,

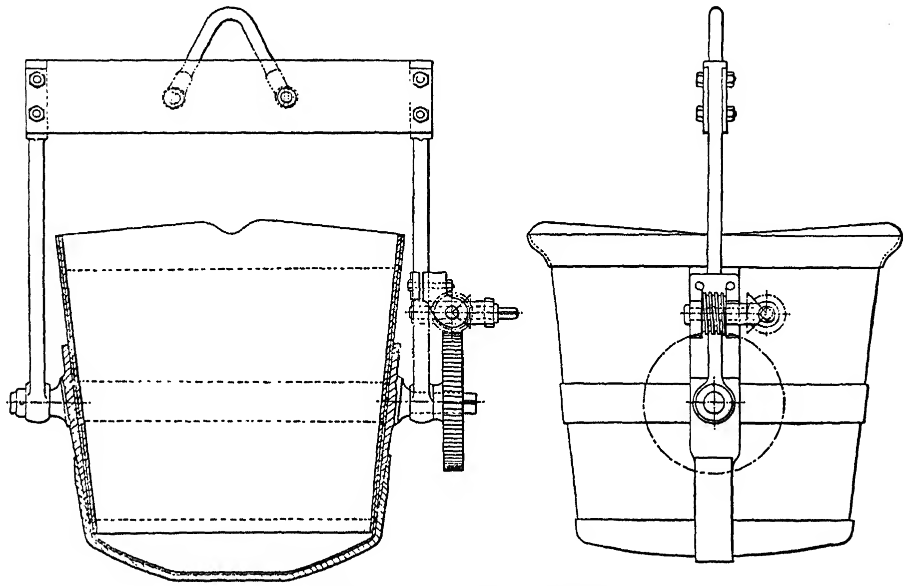


Fig. 59.—Crane Ladle, double geared

forcing the short arm down on the pig. Its valve is actuated by the treadle seen at one side, and counterweighted. The pig is broken at the end that overhangs, but some machines fracture it centrally. Some machines are

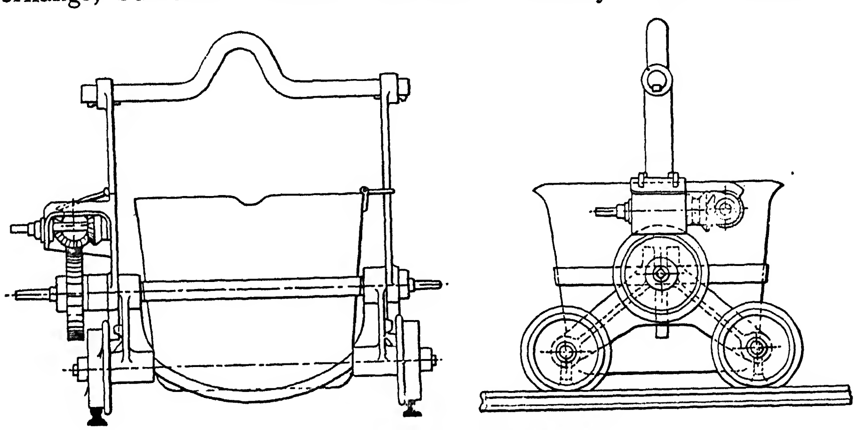


Fig. 60.—Carriage Ladle, double geared

driven by belt, others are electrically driven. Scrap is broken with the sledge if light, and by the dropping of a ball from a crane if heavy. Labour may be saved by using a lifting magnet slung in a crane. This is lowered on the ball, the current turned on, the ball lifted, the current switched off, and the

ball drops. Balls are usually of half a ton weight. Heavy scrap is also cut up with the oxy-acetylene flame.

Steel-melting Furnaces.—These are only used to a very moderate extent outside the great steel works. Some of the larger iron foundries make what steel castings they require in preference to sending away for them. Special designs of furnaces are provided for such cases. Instead of the great open-hearth furnaces which will melt 50 tons, or the immense Bessemer convertors, small " Baby " convertors are used, the Robert, one of the earliest, and the Tropenas being most common. The small furnace can be used for casts as low as 10 cwt. The melting is so rapid that two successive melts can be poured into the ladle for a single cast. Ferro-alloys can be added in the ladle to produce just the amount of recarburization desired. The waste of metal is rather large, and the upkeep costly.

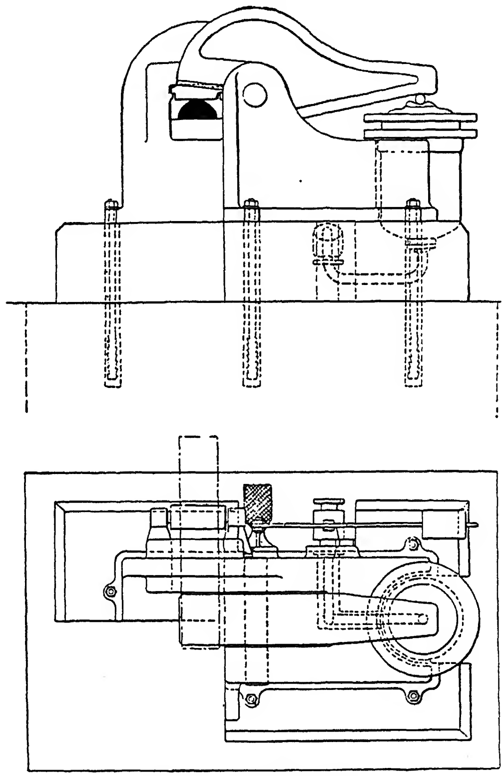


Fig. 61.—Pig Iron Breaker

These convertors are made in capacities of from ½ ton to 2 tons, and they are made to tilt for pouring the charge. The blast is brought in at one side only through tuyeres, and is directed through the metal, or over its surface. A pressure of from 3 to 4 lb. per square inch is necessary. This is supplied from a blower. A cupola supplies the molten metal, which must be melted much hotter than that for the iron foundry, besides which more heat is required to melt the scrap steel included. The latter may amount to from 25 to 50 per cent of the charge.

Brass-melting Furnaces.—While few iron foundries possess a steel plant, there are not many of fair dimensions destitute of a department for the melting of the brasses and bronzes. Castings in these alloys enter into nearly all constructions, and the delays and risks attendant upon getting castings from distant firms render the brass foundry a most valuable annexe to that of iron. A few years ago there was little choice in the matter of furnaces, now they rival the cupolas, both in variety and increased efficiency. Natural draught with coke fuel, blast, oil fuel, and electricity, each with many variations, are now employed regularly.

Furnaces fed with the natural draught of a chimney, and burning coke, the earlier and most common design, are not economical, but for small casts they are not to be despised. The best in this design are Carr's (fig. 62), where the fire bars are placed below the bottom, leaving a space above, through which most of the air passes. The melting is rapid, and the crucible does not sink. The brick lining is carried on a flange within the furnace above the air-space, and a non-conducting backing of broken bricks fills the space between the lining and the outer casing of iron. Furnaces are built to take one or more crucibles. Several furnaces can communicate with flues leading to a common chimney, as in the ordinary brick furnaces.

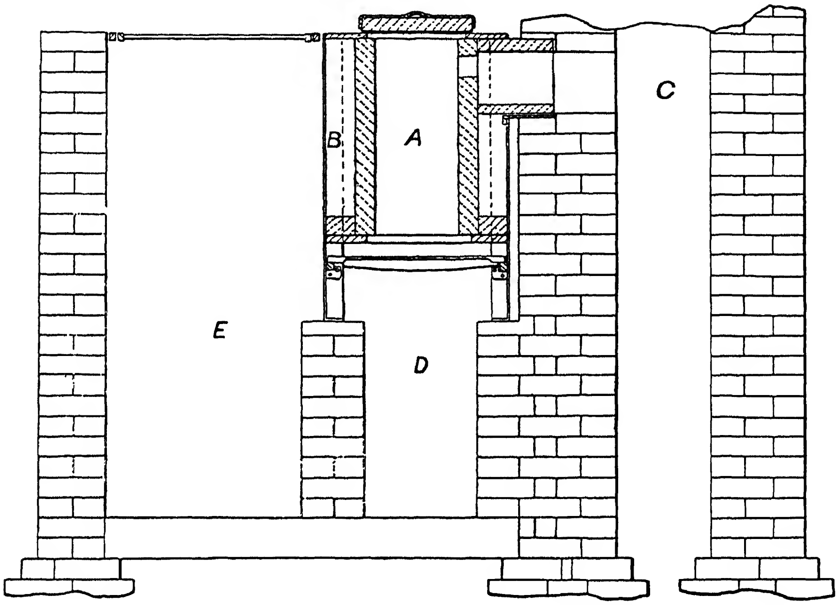


Fig. 62.—The "Carr" Brass-melting Furnace

A, Solid lined furnace. B, Non-conducting space filled with broken brick. C, Chimney 30 to 35 ft. high. D, Ash-pit. E, Pit for taking out ashes.

Improved designs of coke-fired furnaces in extensive use include preheating of the metal, tilting of the crucible while in the furnace for pouring, and the employment of artificial blast. In the first, the metal is placed in a crucible or other annular vessel, above the melting crucible, where it is warmed by the heat escaping from the fuel below, before it drops into the lower crucible. The latter is not removed from the furnace, but both are tilted for pouring. The preheater can be swung to one side when fresh coke has to be charged. This design permits of the employment of larger crucibles, and the attendant suffers less discomfort than when the crucible with its charge has to be lifted out with tongs from above. The employment of blast results in a great saving of coke, when, as is sometimes done, the blast is warmed during its passage by the waste heat from the furnace. It is possible in some of these designs to melt 1000 lb. of brass in one charge.

For large installations, the preference should be given to furnaces that are fired with oil or gas, or with a mixture of each. There is no large consumption of fuel in the preliminary heating up, and no waste of fuel unburnt, at the end of the melt, as there is with coke. The temperature is under precise regulation, and ashes have not to be removed. On the other hand, oil storage reservoirs and supply tanks have to be installed, with pipes, cocks, gauge glasses, and, if the oil is sprayed under high pressure, a supply of compressed air is necessary. If used with a low pressure, a fan or a blower is employed. A low-pressure burner works with air at about 12 oz. per square inch, a high-pressure one at from 20 to 25 lb. per square inch. In the American "Rockwell" furnaces the pressure for the oil is 5 lb. or more, and that for the air is 2 lb. per square inch. Gas may be used instead of oil, with burners and pipe connections modified. 100 lb. of brass can be melted with from 2 to 3 gall. of oil, and after a furnace has been heated with a first charge, 400 lb. of metal can be melted in about 45 minutes.

Electric furnaces are being used in increasing numbers when large quantities of brass are being melted, but chiefly in the United States. Whether they are more economical than the oil-fired designs depends mainly on the relative costs of power, attendance, and upkeep. But there is one important fact in favour of the electrical designs, that the metal is melted in a closed vessel, in a non-oxidizing atmosphere, and that there is then hardly any loss due to the volatilization of zinc, of dirty borings, and of fine scrap. This loss often amounts to 5 or 6 per cent in the fuel furnaces. As a result, alloys can be graded and duplicated with such precision that the average deviation is only about 0·25 per cent. Electric furnaces will not deal economically with small charges, since, with their necessary equipment, they are costly to install, so that, like the oil-fired designs, they are only suitable for the large foundries.

Electrical energy is applied to the melting of brass by two methods: by means of the electric arc drawn between electrodes, or by the resistance offered to a current by its passage through liquid metal, on the same principle as that of the heating of an incandescent lamp. Each design has its advocates, and each has its application in several furnaces that are in successful operation, melting quantities that may range from 200 to 2000 lb. weight. Some of the furnaces are stationary, some tilt for pouring. A few are rocked through an arc to maintain a uniform temperature, and prevent surface superheating, while a perfect mixture of the metals that form the alloy is produced. Generally, the mixture is contained in a bath in the bottom of the furnace. This method is better for heavy charges, but for moderate casts a crucible design of furnace is made, in which the metal is melted by the passage of electric currents through the crucible walls.

The arc furnaces may have the arc drawn between two electrodes of graphite, or of amorphous carbon, provision for the adjustment of which is made by hand or electrically. The heat is transmitted to the metal below by radiation chiefly, although in one design it is directed downwards by a third electrode, placed vertically above, which forces the flame of the arc

down on the charge. Or electrodes are inserted perpendicularly, and the arc is drawn between these and the bath of metal, or the slag or carbon in the trough.

The furnaces that operate by electrical induction must be so designed as to counteract what is termed the " pinch effect ". When the molten metal lies in an open channel in a horizontal plane, a break occurs in the current at an early stage, interrupting the circuit at the point of smallest cross-section, and checking the melting. This pinch effect, which does not occur in furnaces melting steel, has to be counteracted by producing a violent circulation of the liquid metal in secondary channels or loops situated below the charge. This is effected in different ways, in which the electric energy is converted into heat, with rapid movements, sufficient to prevent interruption of the circuit.

Furnaces for Malleable Cast Iron.—Frequently, these are air furnaces of the reverberatory design. To a very small extent, cupolas and open-hearth furnaces are used. As the white iron used has to be melted very hot, the reverberatory furnaces are built of great length, and the metal is tapped where it is hottest. This occurs near the fire bridge, and the bed is sloped towards this part. The fire grate is located at one end, and the chimney at the end opposite, or to one side. The flame passes over a bridge next the hearth, and is deflected on the metal by the low roof, which is usually arched. To facilitate the charging of the metal, the roof is generally made in separate sections, " bungs ", each consisting of an iron framing, enclosing fire bricks. The sides of the furnace are built of steel plates, reinforced with binders, and the foundation is concrete. The lining is of brick, enclosing fire brick, also used for the roof. The working bed is of siliceous sand, and is relined when it becomes burned away.

The annealing of the castings is done after they have been fettled, with the result that the combined carbon is nearly all changed to graphite, and the castings, instead of being intensely hard and brittle, have their strength and ductility greatly increased, so that they have acquired the general properties of iron forgings. The castings are packed in boxes, " saggers ", with hammer scale or hæmatite ore, piled in furnaces, and subjected to a prolonged temperature of from 800° to 900° F. in annealing ovens. The designs of these are numerous, though the principle is simple. The boxes of castings, luted to exclude all air and piled in the oven furnace, are subjected to the heat from solid fuel burnt in a grate at one end, or from gaseous fuel. Flues are arranged beneath the floor, frequently also at the sides and roof, designed with the object of delaying the escape of the hot gases until they have rendered up all their useful heat.

CHAPTER X

Essential Machines and Appliances

The more advanced foundries of the present day employ labour-saving methods to an extent that would have been deemed impracticable a few years ago. Yet in too many shops wasteful ways, which are a financial handicap in competitive efforts, are retained. It seems desirable, therefore, to give attention to this particular aspect of foundry work, dealing with the preparation of the sands, with machine moulding, with fettling, and the lifting and transport systems.

The Preparation of Sands.—Sand when new from the quarry is not suitable for moulds without preliminary treatment. This is performed in isolated machines, or in one large plant, which is only installed in the big foundries. New sands are wet and lumpy, often having pebbles intermixed. Drying is necessary. In small shops this is done in the core stoves, the sand being spread on iron plates. In the bigger foundries, drying cylinders, which measure about 6 ft. in diameter by several feet in length, are employed. They are either disposed with the axis horizontally, or at a slight angle. The sand, fed through a hopper, is carried along the interior of the revolving cylinder with spiral plates, and thrown against baffle plates, which bring it into intimate contact with the hot gases from a furnace that traverse the cylinder. The rotation is slow, being about 1 r.p.m. These machines, in different capacities, will dry from 10 cwt. to 3 tons of sand per hour.

After drying it is necessary to crush, pulverize, and grade the sand. The machines used for these processes are edge runners, disintegrators, riddles, and sieves. Crushing is only necessary with the coarser, harder, clayey sands, and is not adopted with the finer qualities, but instead the lumps are triturated. In small foundries they are broken with a punner, and the product with the ordinary mass is put through a riddle. The machines that crush (fig. 63) are also used for mixing wet loam, hence termed "loam mills". They are similar to mortar mills. The lumpy sand is ground between revolving runners and the bottom of the pan, which is commonly fitted with removable chilled plates. The runners are frequently chilled, or they are steel-tyred. Scrapers are fixed at an angle to heap up the sand in front of the runners. These revolve on their shafts, and are at the same time rotated around the pan on a central vertical shaft. In some cases the pan revolves under the runners. Driving is done through belt pulleys and bevel gears, and the pulverized sand is discharged through a shoot at the bottom of the pan. Many pans used for mixing loam have their rollers deeply indented like huge cogs. These throw up the loam, and amalgamate it very thoroughly. One of these is often used with a smooth roller on the opposite shaft. Some runners again are deeply grooved, in annular fashion.

The next process is the trituration of the sand to bring it into a fine,

loose condition preparatory to passing it through the riddles and sieves. This is done in the disintegrators, which consist essentially of annular rows of prongs carried on a disc, which revolves at a very high speed. The sand

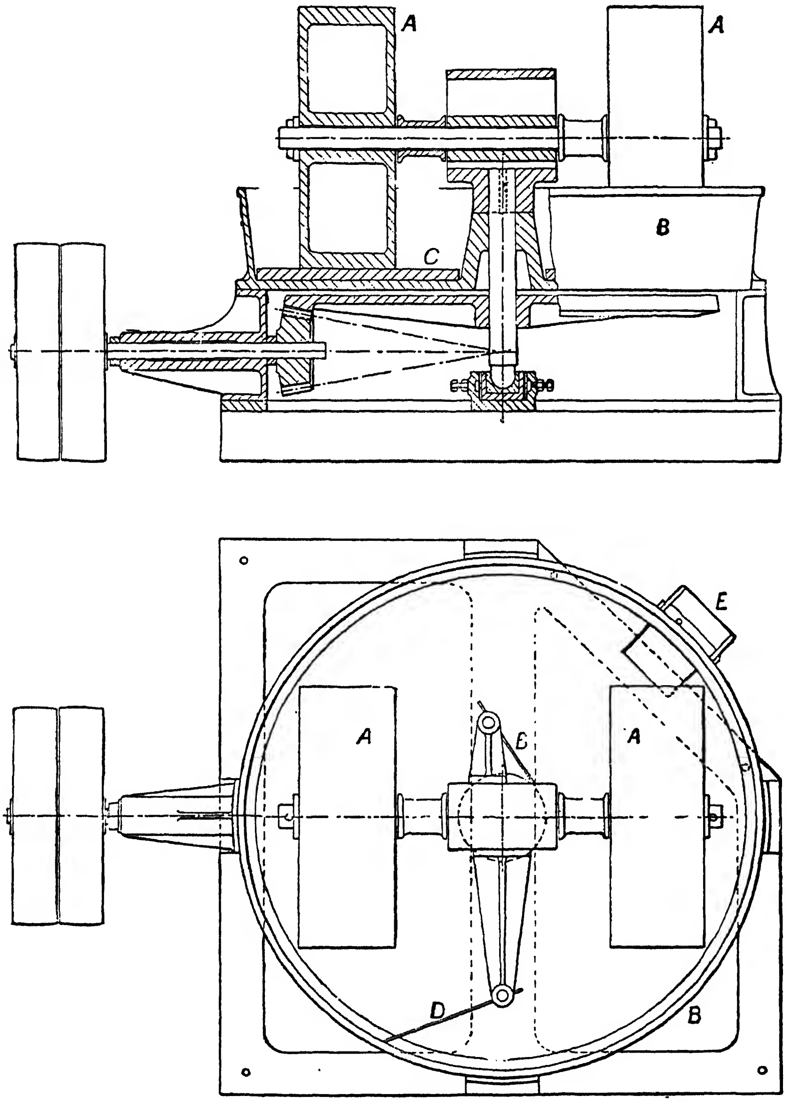


Fig. 63.—Grinding Mill

A, Runners. B, Pan. C, Chilled bottom plates. D, Scrapers. E, Shoot for discharge.

is beaten and thrown about violently. The prongs stand vertically (fig. 64) or lie horizontally in different designs. They are carried on a single disc, or two discs face each other with the prongs on one entering the spaces on those of the other, the rotations being in opposite directions. Or

one may be stationary while the other rotates. The shaft of one disc is hollow to receive that of the other. They are driven with separate belt pulleys, or a bevel wheel on a pulley shaft drives a similar wheel on each disc shaft, in opposite directions.

Riddles and sieves are used to grade sands into coarse and fine varieties, to separate portions imperfectly pulverized, and, in the case of old sand, to get rid of cold shots and nails. The former generally consists of a frame with parallel rods, leaving open spaces of ½ in. or so, while a sieve has a reticulated

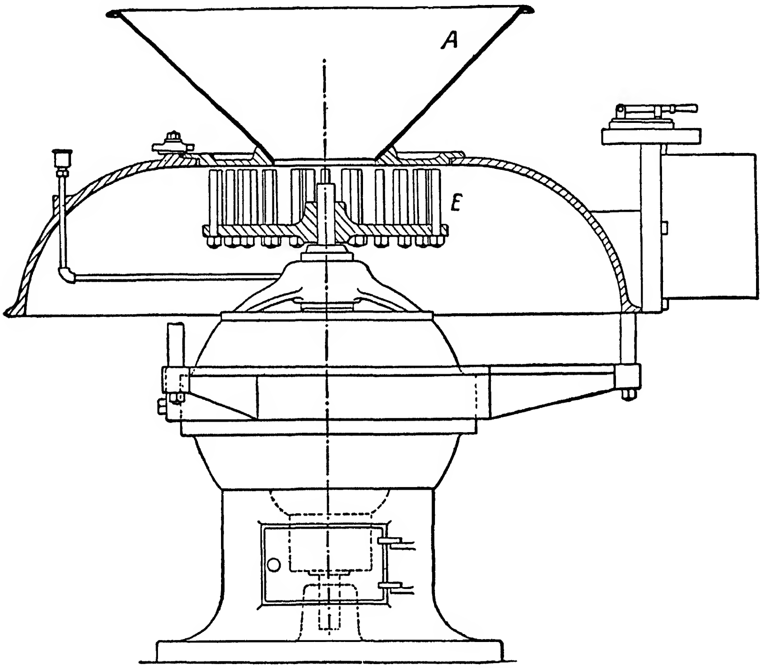


Fig. 64.—Sand Mixer and Disintegrator

A, Hopper. B, Revolving prongs electrically driven.

mesh of crossing wires. Hand-operated riddles and sieves reciprocated on a horse are too slow in action. Any machine is far more economical. The simplest is that in which the ordinary round sieve is attached and locked to a light iron frame reciprocated with a belt-driven pulley and crank. This can make 800 reciprocations per minute, and deal with as much sand as a man can shovel into it, an output of 3 tons per hour being possible at an expenditure of from ¼ to ½ h.p. Larger machines have sieves and riddles made to interchange in a rectangular frame driven by cranks and connecting rods, and sloped at a slight angle from the horizontal to throw the lumps that will not pass the meshes out at one end. Machines of this class will deal with quantities ranging from 3 to 14 tons of sand per hour, with ½-in. mesh, the output being less with finer grading. To deal with larger quantities machines have the sieves arranged on six sides, enclosing the sand, and rotated on a

central shaft, making about 30 r.p.m. A jarring action is produced by the contact of cams, which assists in breaking up the sand, that is also thrown about by internal stays.

Coal is ground to dust in mills provided with heavy rollers, or balls, the first being used within closed cylinders, the second (fig. 65) in open pans. The balls, of cast iron, about 10 in. in diameter, are rotated in an annular path having a concave section of rather larger radius than that of the balls. The same mills may be used for pulverizing sands.

In the largest foundries these units are associated in one automatic system

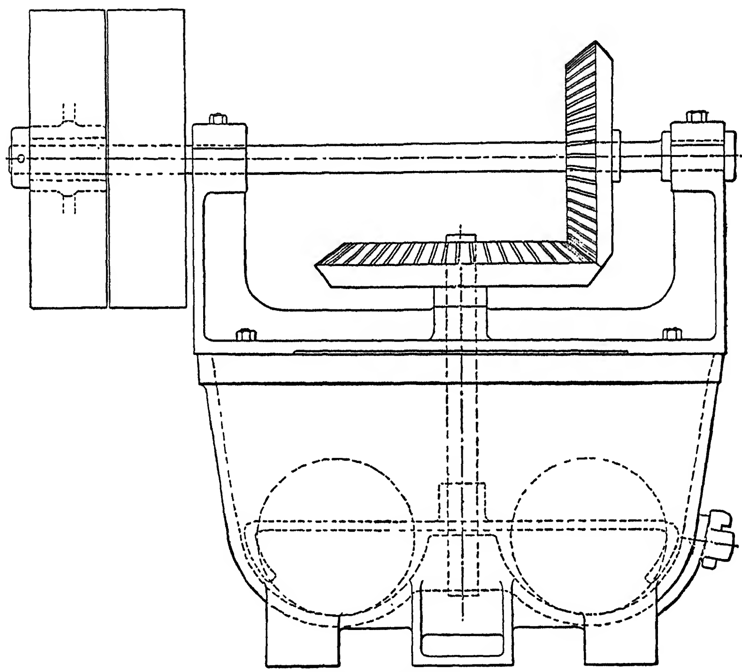


Fig. 65.—Coal Mill

for continuous treatment. In general, the arrangement is as follows: raw sand is thrown into a hopper at the base of an elevator, which discharges it into a drying oven. Thence it goes into the grinding mill, afterwards into a polygonal sieve, and then to a mixing apparatus, where the coal dust is added in the correct proportion. The old sand is treated in another part of the plant, conveyed for admixture with the new, the product elevated into a disintegrator, mixed, and stored in bins for use.

Machines for Moulding.—It is not possible to describe here, even in barest outlines, the leading types of these machines, of which the useful varieties must now be numbered by hundreds. The only way to treat this immense subject is to state with brevity the forms and utilities of the principal elements in their designs, with comparisons of the methods and economies of their operations.

Mention has been made on a previous page of the loss of time involved in the preparation of a dummy box of sand, on which the parting joint is

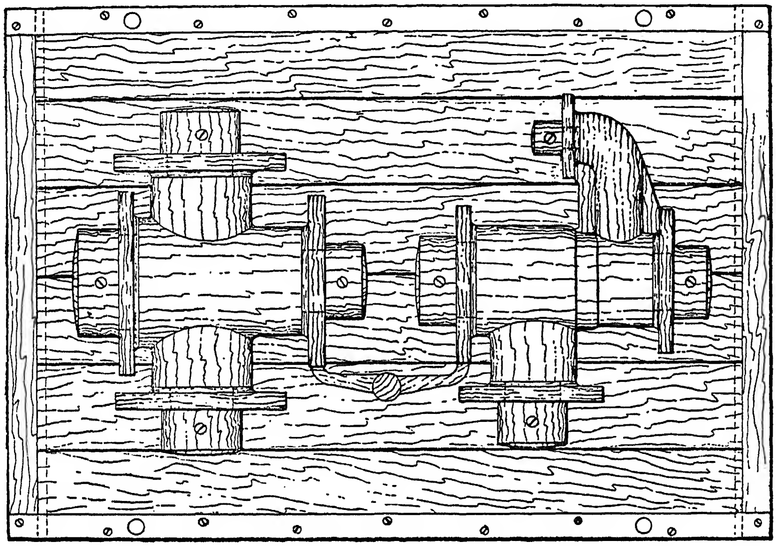


Fig. 66.—Valve Body Patterns of Wood mounted on Wooden Plate. The plate, cleated at the ends, has open joints and strips of hoop iron to secure box pins.

made in moulding by turning over. This wasteful method is avoided in all machine moulding, as it is also in all odd-side work, and in the plating of

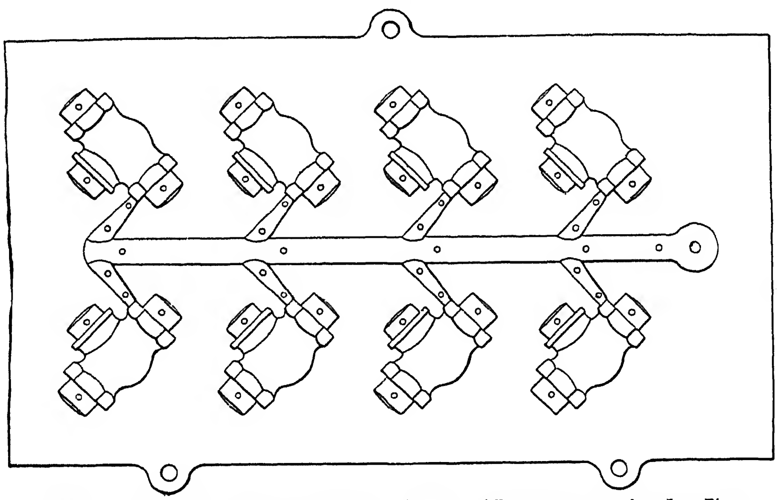


Fig. 67.—Cock Body Patterns of Metal with Ingate and Runners mounted on Iron Plate

patterns, an immense amount of which is done without any assistance from machines. As these are more widely utilized the value of the odd-side lessens, while that of plating grows. Its basis is the plain bottom or joint board

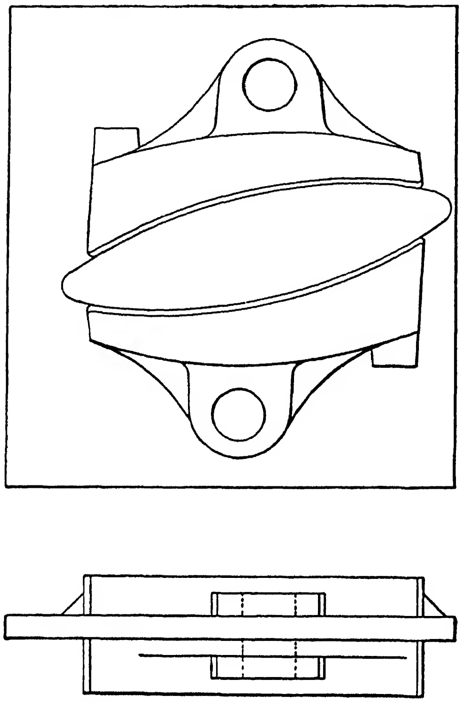


Fig. 68.—Brake Blocks mounted on Plate

independent of its pattern, which is laid on the face of the board. To this the bottom box or drag is pinned before ramming. The time otherwise occupied in making a temporary sand bed on which to ram the drag (to be afterwards thrown away) is saved, and the board provides a true joint plane without strickling and sleeking it with the trowel. From this to the permanent mounting of a pattern or a portion of a pattern or more than one pattern on a plate of wood (fig. 66) or of iron (figs. 67 and 68), where pattern portions are attached on opposite sides of the same plate, is a natural development, as is also their transference from the floor or the work bench to the table of a machine. Economies do not cease here, but they increase when joints are of non-plane shapes, combining slopes and curves, and when several patterns are mounted on one plate, each requiring a separate runner. In these cases it is usually preferable to cast pattern parts, plate, and runners all in one piece, than to adopt the method common with plane plates of preparing the patterns separately, and attaching them to their plates with screws or rivets.

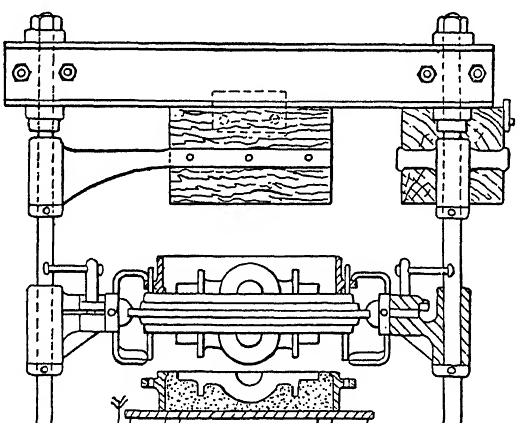


Fig. 69.—Turn-over Table Machine, with presser head above and carrying-off table that runs on tracks below. Pattern parts are mounted on plate attached to the table.

Obviously, the moulding table is the first important element in any machine, since it is the plate to which the pattern parts are attached directly, or to which the patterns, already mounted on their plates, are secured. Tables either turn over, to bring each face uppermost (figs. 69 and 70), or they are

fixed (fig. 71), in which case only the top face is used. In a relatively small group, top and bottom faces of fixed tables are used, by pressing boxes of sand simultaneously against pattern parts mounted on each face, these being worked hydraulically (fig. 72). Using a turn-over table, the sand is rammed (fig. 73) or pressed (figs. 69 and 70) over the pattern portion on the upper face. After being turned over, with the box, the latter is withdrawn downwards, and the other portion of the pattern, on the opposite face, being brought upwards (fig. 74), is rammed. The closed mould is seen in fig. 75. The majority of machines of small and medium dimensions have

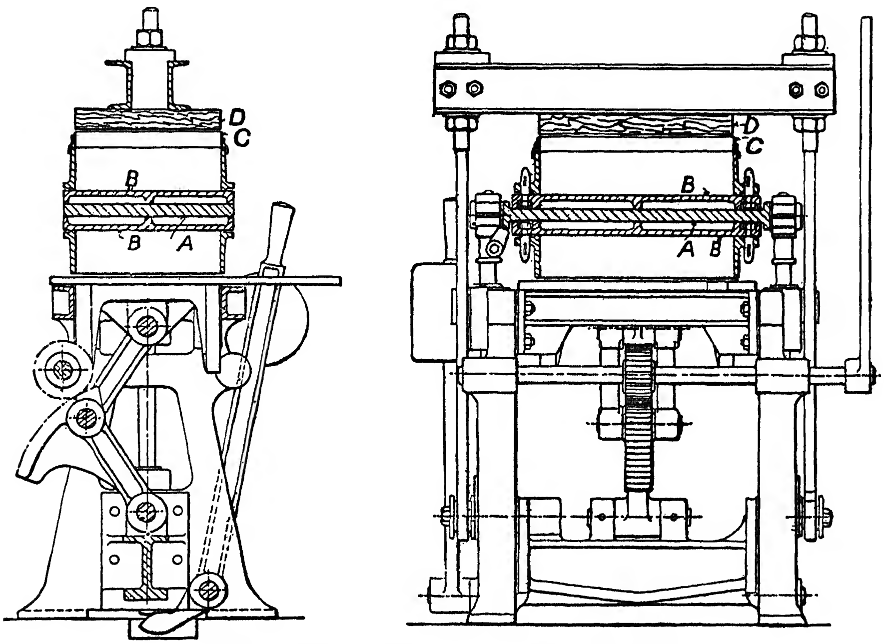


Fig. 70.—Hand-moulding Machine with Turn-over Table

A, Turn-over Table. B, Plates to secure patterns. C, Sand frame. D, Presser head.

tables of this kind. The large machines must generally have fixed tables. In these, the mould is lifted off its pattern with rods or "stools", or with power. In some designs the table is rocked over to permit of the lifting of the pattern out of the mould, or, in a very large number of cases, the pattern is withdrawn downwards through a stripping plate (figs. 71, 76, 77, 78), this being necessary in all those patterns which have deep perpendicular sides, and desirable even when depths exceed 3 or 4 in., being beyond the limit at which delivery can be assisted by rapping.

After plating, the two important details in the moulding operations are ramming and delivery. Mechanical aids are provided for these in most machines, but not in all. The cost of hand-ramming increases with the dimensions of the mould, and with the intricacy of its details, so that several hours may be occupied thus in moulds measuring several feet across. Here

the machines afford great economies, since they will "press" or will "jar-ram" the largest moulds within their capacity in a few minutes, the time spent depending chiefly on the rapidity with which the sand is thrown into the box part. The amount required for compression is measured within a sand "frame" of wood or metal (fig. 70). Except in the deeper moulds, and under loose, projecting pieces, no preliminary peg-ramming is required, but two or three squeezings with the presser head suffices. In the jar-ramming machines a few bumps consolidate the sand in the deepest moulds. These therefore, after the plating, afford the chief economies of machine work.

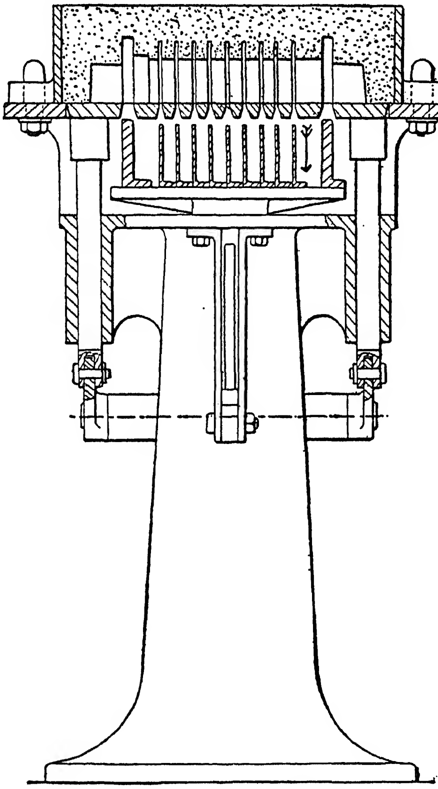


Fig. 71.—Radiators and Flanges of Motor Cylinder drawn through Stripping Plate in a Fixed Table A

Delivery of patterns by hand is only the work of a minute or two. The advantage of using a machine is therefore that it substitutes an accurate mechanical lift for the unsteady action of the hands, and that in very many instances the employment of stripping plates prevents breaking down of the sand, and consequent mending-up, with inaccurate results. Some machines do not include this, but their utilities are confined to the shallower patterns, and those whose shapes favour delivery. The mechanical withdrawal is furnished by means

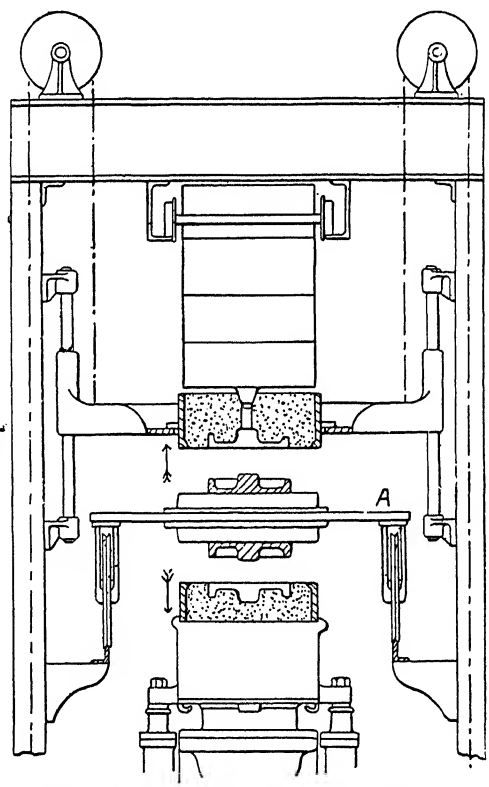


Fig. 72.—Boxes Pressed and Delivered in Unison on a Non-turn-over Table A

of guides that rigidly control the downward movement of the pattern away from its mould, or the upward lift of the box off its pattern. A little rapping

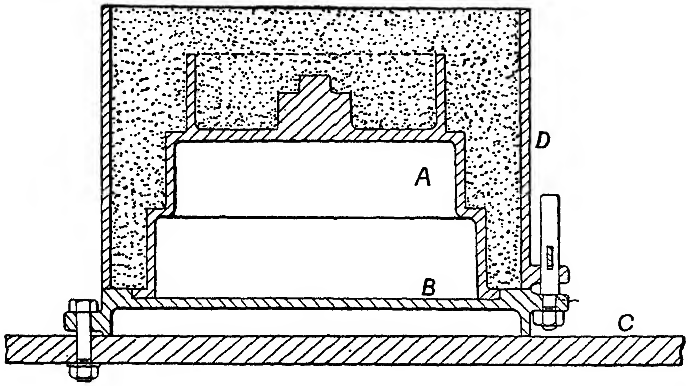


Fig. 73.—Bottom Box rammed over Pattern, then tabled, turned over, and mould delivered

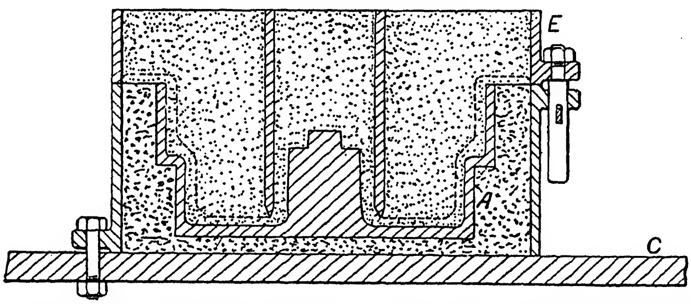


Fig. 74.—Top Box rammed over Pattern, embedded in Plaster of Paris, then turned over and delivered

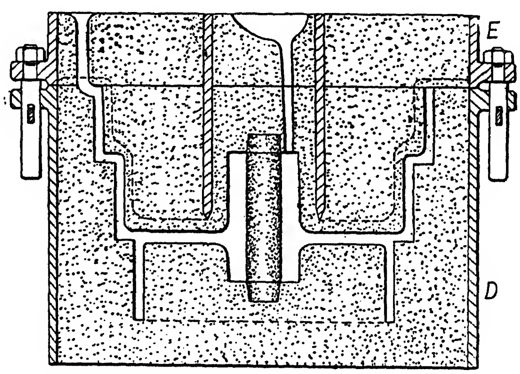


Fig. 75.—Mould Closed and Completed

Figs. 73–75.—Cone Pulley moulded on a Darling & Sellers' Machine
A. Pattern. B, Its mounting. C, Table of machine. D, Bottom box. E, Top box.

is done, which does not sensibly enlarge the mould, like lateral hand rapping, but loosens the contact of the sand slightly. Either a hand mallet is used, striking blows on the table, or a pneumatic piston produces vibration.

The most remarkable fact in connection with machine moulding after that of the very numerous variations in the designs in use is that of the

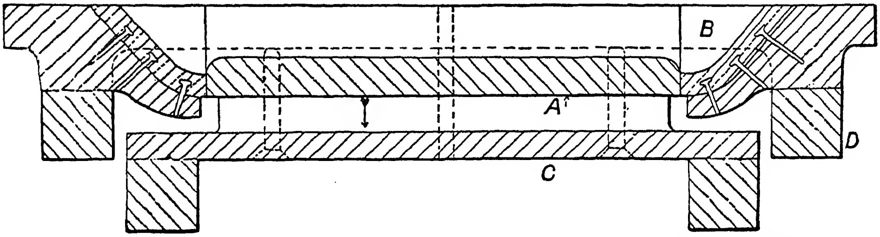


Fig. 76.—Portion of Pattern A being drawn through Stripping Plate B lined with White Metal. C, Pattern plate. D, Frame of Machine.

enormous growth in their dimensions and capacities. Patterns, the castings from which weigh several tons, are moulded on jar-ramming machines, and

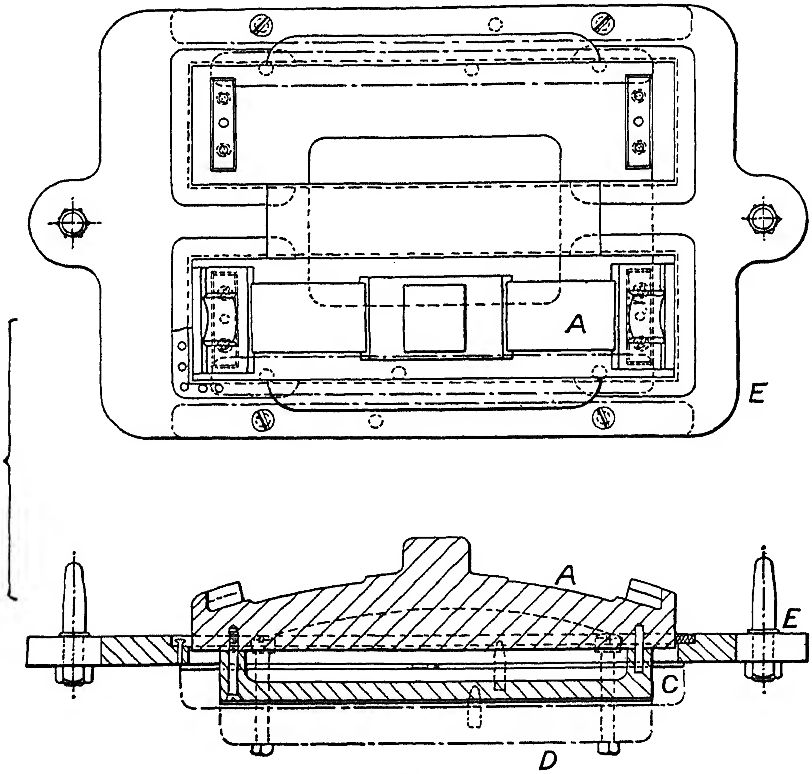


Fig. 77

Figs. 77 and 78.—Brake Shoe, pattern part moulded
A, Pattern part for bottom. B, That for top box. C, Pattern plates.

those of several hundredweights on hand-operated kinds. Though the movable parts are heavy, their mass is counterweighted with weights or springs, and movements are rendered easy with levers and gears. For power

chines compressed air or pressure water are employed. Associated with se machines are conveying systems for sand, flasks, and finished moulds. ltiple moulding (fig. 79), where moulds are poured in piles, is sometimes pted for small castings made in quantities.

Machines for Fettling.—In small foundries the castings are cleaned h little or no aid from machinery, the value of which grows with output. ıen a casting is taken out of the sand in the morning, nothing is done to n the moulding area, but it is transported to the fettling shed, where the es are extracted, the runners and risers cut off, and a general examination de to ascertain whether it is entirely sound before doing any work upon If satisfactory, runner marks and fins are removed, together with all plus lumps and adherent sand. This is done by hand with chipping sels, coarse files, and scratch brushes of wire. But better methods are ilable.

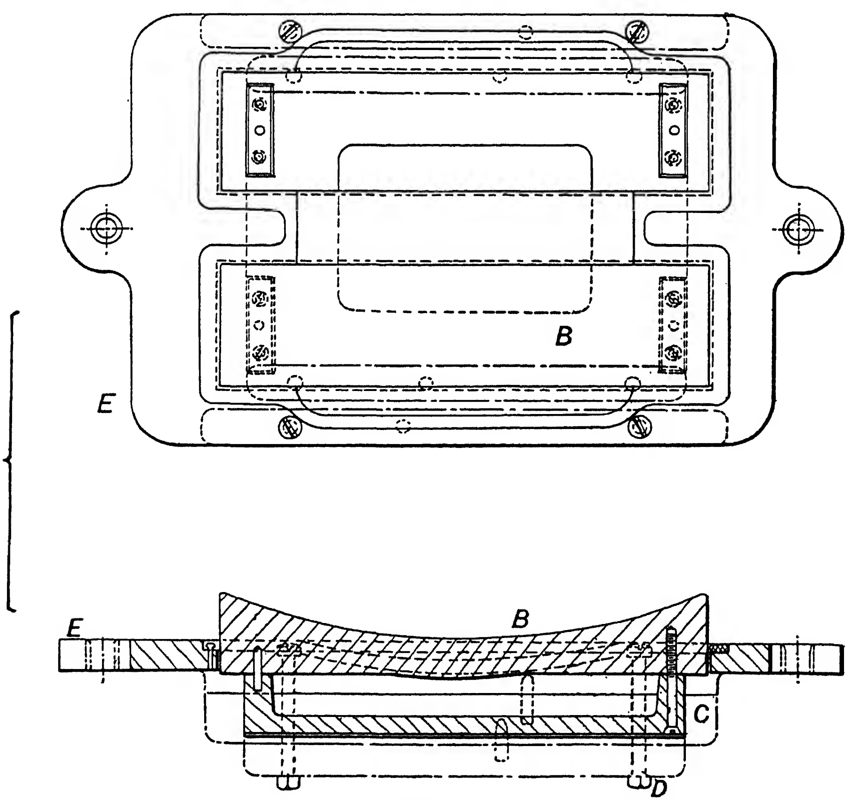


Fig. 78

Stripping Plates on "International" Machine
rame of machine. E, Stripping plates lined with Babbit.

In the larger foundries, runners are cut off iron castings with a circular v; for those in brass, a git cutting machine is used, which consists of two posed chisels actuated through a reciprocating slide, with power. These

are not only more rapid in action than the severance by hand, but they involve no risk of tearing out the metal below the surface of the casting. This is liable to occur when runners are knocked off with the hammer. This may be prevented by nicking all round with a cold chisel before using the hammer. In any case the surface has to be smoothed by chipping and filing, which is avoided when a machine is employed for severance. Fins occur more or less on all castings, following the mould joints, and the fitting of cores in their print impressions. These are laboriously removed with hammer and chisel. The pneumatic chipping chisels are far more efficient. Much economy of time results in this kind of work, and in smoothing lumpy and rough portions, when emery grinding wheels are installed. The larger sizes are mounted on a floor stand, the smaller on a work bench. To deal with castings that are too large to be handled and presented to the fixed machines, wheels are mounted on suspended arms to be swung by the workman into any required position.

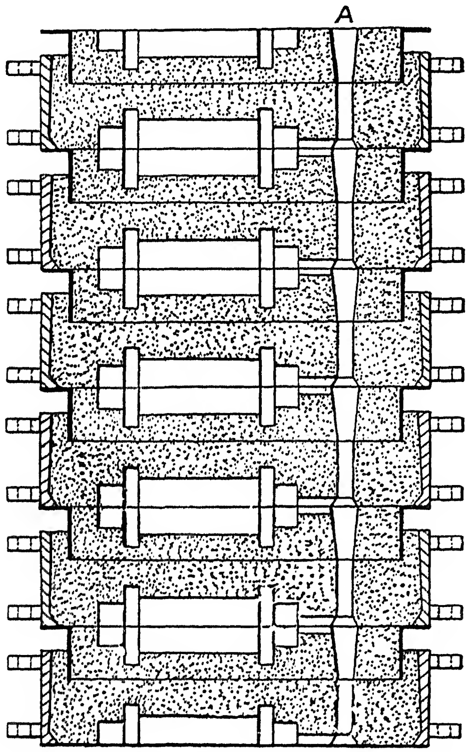


Fig 79.—Multiple Moulds poured in Piles through Ingate A

When large quantities of small castings have to be smoothed, this is done, after preliminary grinding for the removal of fins and excrescences, in a tumbling barrel or rumbler. This is a cylindrical vessel from 18 in. to 36 in. in diameter by from 30 in. to 60 in. in length, rotated round its longitudinal axis about once in a second. Within this the castings are tumbled in contact with small "stars", and are smoothed and polished by the mutual friction set up. Iron is tumbled dry; brass, with water. The driving is done with a belt direct, or through gears, or the drums run on rollers. Its axis is horizontal or inclined. Polygonal drums are made, with chilled lining plates.

Since large castings cannot be put in tumbling barrels, these, in the more advanced foundries with a sufficient output, are treated in a sand-blasting plant, for which an air compressor, giving a low blast pressure ranging between 5 and 25 lb. per square inch, is necessary. Having a suitable plant, castings of any sizes and weights can be cleaned. The castings are placed in a room, constructed of sheet iron, having a perforated steel floor and a glass roof, well ventilated. The sand, propelled by the air pressure, is

directed through a nozzle held by the operator to any portion of the castings. The sand falls through gratings in the floor into a hopper, to be drawn by an exhauster back to the sand-supply. The attendant is protected with a helmet of felt or leather, covered in front with sheet rubber, which prevents dust getting into the lungs, and material from striking his face. Air for respiration enters through a hose at the top, the expired air passing out between the lower part of the helmet and the shoulders. Glass is not used for the eyes, since it would become obscured, but fine wire gauze instead. Quartz sand is used, but chilled iron sand is better. It is prepared by atomizing a stream of molten iron with jets of steam projected into a tank of water. There are several designs of sand-blasting plants now in use.

Lifting and Transport Systems. — The calls for hoisting and transport are incessant in the foundry. Much time will be wasted if the provisions made for these are inefficient. The overhead travelling crane is the best machine to install, because it will command the entire area of the shop. Its power must be rated by that of the weight of work being done. The most economical design is the three-motor crane, in which the motors are respectively rated for hoisting, travelling, and cross-traversing. Cranes of different powers are installed in different areas, to suit the work being done. It is well to supplement these with a few swinging jib cranes located in areas where mould parts are likely to monopolize the crane service for considerable periods. As these are attached to the columns that support the roof, they do not block any shop area. Very light moulding makes few demands on cranes, and overhead tracks, from which depend pulley blocks, or light hoists are often provided for these departments. An equally good alternative is a light overhead traveller, worked with a dependent rope from below. Many of these are driven electrically.

The overhead cranes transport as well as lift rapidly, taking moulding boxes and castings along the shop, and transporting ladles of metal. But, since their movements are confined by the shop walls, they have to work in association with extramural tracks, entering a few feet within. These are of standard gauge to communicate with the yard tracks. Here the question arises of employing floor tracks throughout the length of the foundry. When these are laid down, as they often are, the gauge is 18 in. or 24 in. But they are only desirable in the departments that deal with the lighter castings. Where heavy moulds are being handled, the floor tracks are of less value than the overhead travellers, and it is difficult to keep them clear of mould parts in the morning, when these are laid open for cleaning and coring. In long shops, devoted to the light work, they are useful for general service, even though a light traveller is employed.

CHAPTER XI

Shop Arrangements and Organization

Only one design of foundry is regarded with favour now, a rectangular building, parallel, with unobstructed roof light, and comprising one bay, or more often two or three, each bay with its own roof, but without obstructions in the shape of separating walls. A clear area is thus included between the outer walls that permits of ready intercommunication and efficient supervision. Within these bays, the work of different departments is carried on in strictly localized areas, each being served with the cranes and tackle that are specially adapted for the work to be done. These departments in the majority of foundries include heavy green sand, light green sand, plate and machine moulding, often subdivided further, to locate castings made in quantities by themselves, loam moulding, and core making. These classes of work are done by separate groups of men who seldom handle any other branch, having developed the faculties of experts. In addition, the melting of metal is the exclusive task of the furnaceman and his helpers; sand grinding and mixing occupy other hands; fettling is done in a separate room. Crane operators are required, and there is a large proportion of loading, carrying, and attendance on the moulders that engages the services of a body of unskilled labourers.

Roof spans may range from 30 to 40 ft., depending on the bulk of the work done. A height of about 25 ft. to the spring of the roof is suitable. If symmetry is desired, spans should be equal and heights uniform, so that future longitudinal extensions are simplified. The enclosing walls should be of brick. The internal roof columns may be either of cast iron or built up of steel bars and rolled sections. In each case attachments can be made to receive the pintles of swinging jib cranes. The main section usually terminates with the runways for the overhead cranes, and a separate smaller section is carried up to the roof principals. A ridge roof is usual, with a ventilating louvre surmounting. The principals are of steel, formed of tee sections and bars. It should be covered with slates, laid on felt, spread on boards. Illumination is provided by a continuous skylight along each ridge, or along the north ridge only. An alternative is the saw-tooth roof, with north light, but this is not nearly so common as the symmetrical design. Puttyless glazing should be used, and a thick glass. Windows are not necessary in the brick walls, but they relieve the otherwise depressing effect. As in most cases, the cupolas and the machines, together with the sand and coke stores, are located outside and close to the main building. This precludes the employment of windows there, but they can be inserted in the opposite side and in the end walls.

The minute subdivision of tasks that is familiar in the big machine shop does not exist in the foundries. Men are occupied in one or other of the leading sections previously mentioned, beyond which they seldom go. But

the more specialized the firm's manufacture becomes, the greater is the scope for the introduction of separation of tasks within the great subdivisions. Thus, different sets of men will be engaged on the making of large and of small cylinders, on pulleys, gear wheels, railway chairs, or any other articles that are produced regularly in large quantities. This becomes amplified in some machine work where the production of a complete mould is the combined result of the labours of several men, none of whom are moulders in the sense of being craftsmen. And while in the general class of foundries the work is mostly done by the day, in all specialized tasks payment by the piece is adopted. One foreman, with an assistant and a clerk, suffices for the supervision of all the departments, but each has generally a leading hand, who, by virtue of his experience and reliability, is placed in charge of it, directing the routine, while he himself is engaged in the general work of the department.

THE MACHINE-SHOP

BY

JOSEPH HORNER, A.M.I.Mech.E.

The Machine-shop

CHAPTER I

The Work of the Machine-shop

Changed Aspects.—This department of the engineers' factory shows changes more extensive than those which have occurred in any other, even though the foundry and the smithy have been considerably remodelled. To an old craftsman the changes are remarkable. A few years ago, the cost of machining was so high that it was avoided as far as possible, and the work of the foundry and the smithy was arranged to this end. Those were the days of cored holes and "black fits", when the pattern-maker and smith were brought to book if undue allowances were left for machining. It was the period, too, of weak machines, of single-cutting tools, mostly made of carbon steel, with only a meagre proportion of "Mushet" tools. To-day opposite conditions rule. Coring, black fits, and scanty allowances for machining are discouraged. Holes are drilled in the solid; pieces of fairly large dimensions are turned, bored, and cut off from solid parallel bars; and, instead of being made from expensive forgings, articles are shaped from blocks of metal first severed in the ubiquitous hack-sawing machine, then chucked and reduced rapidly.

The Causes of Changed Practice.—These reforms are due to several causes. There is an intelligent distrust of some of the old long-standardized methods of dealing with certain articles on certain machines, and new methods of solving problems of machining are justified by results. Another improvement is the increased strength of machine-tools, which is accompanied by more rational design and a general speeding-up. There are also improvements in the forms and in the materials of the cutting-tools used, and of the very numerous appliances, such as jigs, fixtures, and devices for multiple and continuous machining. A rigid system of gauging is now in vogue. These and other influences have brought the machine-shops of to-day into strong contrast with their forerunners.

The manufacture of small arms, the smaller machines, motor vehicles, aero-engines, and so on, in large numbers, has called for the production of thousands of similar parts with fine tolerances. This work has had to

be done with a minimum of skilled attendance, and has been accomplished at an almost fabulous reduction in costs. The special machine and its set-up of tools is the dominating fact. It secures the degree of accuracy desired with continuous production, and eliminates the special fitting of parts which used to take place, and substitutes " assembling " for this costly operation.

An immense number of such special machine-tools has been designed. Concurrently with this developing, new appliances have been schemed to assist and extend the purposes to which the machines may be put, and to economize the time of the attendants, and incidentally to relieve them of responsibility. Always, the essential point is that accurate work is produced in large quantities, while its cost is greatly lessened.

Machining Elementary Forms.—If the elementary geometrical forms machined are observed, they will be found to be simple and few in number. They comprise plane, cylindrical, and helical surfaces, though in great variety. These are practically all; yet the types of machines built to form these very simple shapes are numbered by the score, and the individual designs run into hundreds. Yet the numbers constantly grow—hardly a week passes but some new machine, possessing some special feature, is placed on the market.

The role of producing any one of these simple geometrical forms is not confined to one method or to one kind of machine. A plane surface can be produced in the planer, shaper, slotter, drilling or boring machine, the lathe, the milling machine, or the grinder. A cylindrical surface can be machined in the lathe, the boring and turning mill, or the grinder, and, with some limitations, in the drilling machine, the shaper, and the slotter. An internal cylindrical surface (bore) can be made in the lathe, the drilling or boring machine, the milling or grinding machine. A spiral or helical surface can be produced in the lathe, the screwing machine, the milling machine, or the grinder. Special shapes may be cut in lathes provided with " forming " slides, and with suitable tools; in milling, grinding, and broaching machines, and in gear-cutters. Similar forms are produced on several kinds of machines, and this fact has had a vital bearing on the changing practice of the present day. The machine chosen is the one which will do the work required best and most cheaply. Three considerations arise: (1) the selection of the best method or machine; (2) the dimensions of articles and the relative positions of the parts to be machined; and (3) the degree of accuracy desired.

1. The Selection of Machines.—It is not always easy to choose the best from several possible machines. Machines naturally fall into groups, and some machines of each group are better fitted than others for the performance of certain tasks. It does not follow that because a planer will work on short pieces it is the best tool for dealing with all short articles. The shaper or slotter may be better. As a general principle a reciprocating machine-tool should not be employed if a rotating one will produce satisfactory results. Nor ought short screws to be produced on the screw-

cutting lathe if other machines designed specially for cutting short screws are available. Certain jobs are allocated to certain machines because they have proved most suitable in practice.

2. Dimensions.—The dimensions of articles to be machined naturally determine the size of the machines used. The size of the machine is specified in different ways, depending on the kind of machine. The lengths of planer and other beds, the dimensions of tables, the swing, and the centre-distance of lathes, the sizes of chucks, mandrels, and so on, determine the "size" of the machines. The machine may take either a single large piece or several smaller pieces; thus a series of articles may be put in tandem on a machine-table, or be disposed around a chuck, or two or more articles may be placed on a mandrel.

3. Accuracy.—The degree of accuracy desired is the factor upon which the interchangeable system of manufacture depends. Certain "tolerances" are allowed, and if parts which are to fit together comply with these tolerances, any part A will fit any part B: for example, suppose a $\frac{1}{2}$-in. spindle is to fit a hole approximately $\frac{1}{2}$ in. in diameter. If the hole is drilled so that its diameter is less than 0·505 in., and more than 0·495 in., and the spindle is turned so that its diameter is less than 0·495 in. and greater than 0·49 in., then any spindle turned to these tolerances will fit any hole bored to the tolerances stated for it. The tolerance allowed in the hole is $0{\cdot}505 - 0{\cdot}495 = 0{\cdot}01$ in. The tolerance allowed for the spindle is $(0{\cdot}495 - 0{\cdot}49) = 0{\cdot}005$ in. Now it is clear that the finer the tolerances the more difficult and costly is manufacture. What then is the advantage of fine tolerances? The advantages are that a noiseless smoothly-running machine can be built which will have great freedom from wear, because the moving parts have no room in which to knock themselves to pieces. The contrast between a Rolls-Royce and a Ford car engine is largely one of contrast between tolerances. In one case we have an expensive, smoothly-running car which is cheap to maintain, in the other a cheap car, but one with higher maintenance costs.

The Machines.—In a study of the machine-shop, some knowledge of the standard machine-tools must be assumed—we are here chiefly concerned with the later developments which have followed the changing practice of the present day. It does not harmonize with that practice to deal with the machines, as of old, in watertight compartments. The work of allied groups frequently overlaps. What is of moment now is the modern way of regarding the vast subject of machining, the reaction of this view on machine design and selection, and on shop practice.

CHAPTER II

The Tools

GROUP I

Single-edged Cutting-tools.—These are used in the lathes, planers, shapers, and slotters. They are so termed because each tool has but one edge, which distinguishes the group from the reamers and milling-cutters, which have several edges acting in quick succession. They are an obvious survival from the period when tools were presented by hand.

Formerly these tools were ground solidly with the shank or bar on the end of which they were forged. Later, they have been more frequently made separately, as tool points, to be gripped in holders, of which there are many scores of designs. The expense of a higher grade of steel can then be incurred for the small tool point, and in many instances tool points can be disposed and operated to much greater advantage than when they are forged solidly on long shanks. These holders occur in several machines, but principally in the newer lathes, in automatic turning machines, and turret lathes. They reach their highest developments in the latter.

Tool Angles, Rake.—The term "single-edged" includes some dozens of ends and edges shaped differently, some being true cutting-tools, others scrapers only. The essential difference between cutting-tools and scrapers is that the first has top rake, the second has none, that is, in the first the top face of the tool makes an angle of something less than 90° with the surface of the work, if plane, or with its tangent if circular; while in the second the angle is 90°.

The "tool angle", the angle of "clearance", and the angle of "top rake", are shown in figs. 1 and 2. The tool angle is a measure of the ability of the tool to resist the pressure of the cut, and it is therefore maintained as large as possible. The clearance of 6° (figs. 1 and 2) need not vary much, since this clearance is provided merely to prevent friction and heating between the tool and the surface of the work. It may range between 3° and 7°, though many tools that are hand ground have a larger amount, by virtue of which they cut more freely, but at some sacrifice of endurance. The angle of top rake is varied with the material to be tooled in order to give a good cutting action, and to permit the chips or the shavings to come away freely.

The tool angle ranges from 50° to 85°, both being exceptional. Keen angles would give an easy cut, but the edge would not be permanent. Two standard angles have emerged, roughly 70° for the softer steels, and 80° for the harder steels and cast iron.

Figs. 1 and 2 show standard Sellers' tools. Two sets only of angles are adopted (fig. 1), the "blunt tools" for cast iron and the harder grades of steel, and (fig. 2) the "sharp tools" for wrought iron and the softer grades of steel. Both are made as right- and left-handed straight tools, or as right-

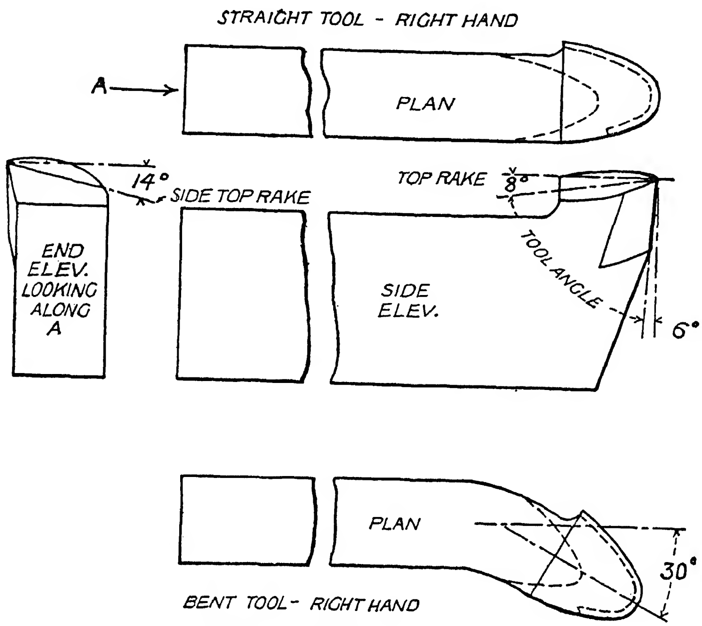


Fig. 1.—Standard Round-nose Tool

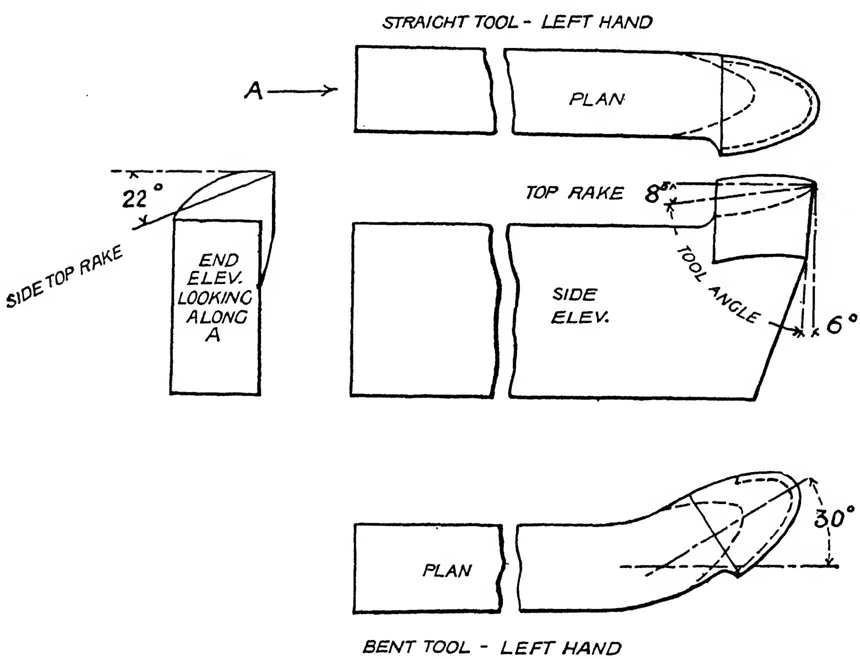


Fig. 2.—Standard Round-nose Tool

and left-handed bent tools. The angles are stated on the drawings. The difference lies in the side top rake.

Side Top Rake.—When considering top rake it is necessary to bear in mind the direction in which a tool is fed in relation to the work. If it is traversed laterally, as in turning, then a straightforward nose with front rake only is not the best possible, because the tool angle is not in the line of travel and the lateral strain on the tool is increased. But if rake is provided in the direction of travel—"side top rake"—the tool can be fed more easily, will cut more freely, and the chips will be deflected away from the tool support. This explains why the majority of roughing-tools have side top rake, and why, when a straightforward tool is employed, it is generally set at an angle for traverse cuts, and why so many tools with top rake are bent at the points right and left to correspond with the direction of their traverse. The blunt tool in fig. 1 has 14° of side top rake, and the sharp tool (fig. 2) has 22°.

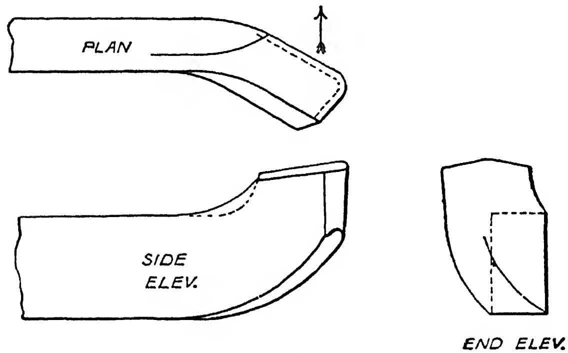


Fig. 3.—Double-edge Roughing Tool

Plan Outlines, Roughing and Finishing.—The curvature of the nose of a cutting-tool is important. Figs. 1 and 2 show "round-nose" tools. These gouge-like tools remove material with the maximum of effect. The amount of convexity varies considerably, and generally those with the longer radii are used for the heavier duties. These are termed roughing-tools, notwithstanding that they are often retained for finishing. The distinction between tools for roughing and finishing is not observed to the same extent as of old. The spring-tool, so long a favourite with turners, is obsolete. Tools with double edges (fig. 3), such as are commonly used in lathes, rough with the leading edge, while the small following radius leaves a smooth surface.

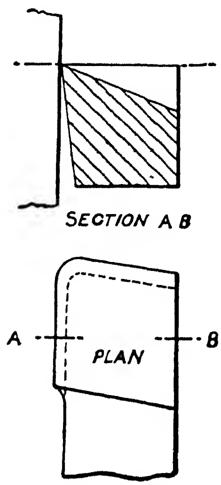


Fig. 4.—A Knife Tool

Knife Tools.—The knife or shaving-tools are employed extensively in turret lathes. They rough and finish. They cut normally to the knife edge (fig. 4), and remove broad shavings with fine feeds, leaving a finished surface on the work. They are made straightforward, left-handed, and cranked. A clearance of 6° and a side top rake of 12° is suitable. Allied to the knife tools are the narrow parting-tools, used for severing pieces of work. These are made straightforward, left-handed

and cranked. They have no top rake, but only front and side clearances. There is also a slight clearance from the front backwards.

Tools with Profiled Edges.—These form a very large group, used only for finishing without traverse. They have no top rake, are used indifferently for all materials, largely in the lathes, and only to a very limited extent in reciprocating machines, since the work is done better with profiled milling-cutters. A familiar form is the "vee" tool, employed in cutting screw threads. As these have to traverse, 8° is a suitable side clearance for them. They are often made right- and left-handed, with a larger clearance on the leading edge. They are also straightforward and bent.

GROUP II

The Drills.—Few drills are used now except those of the twist design. None of these are strictly standardized, except in the practice of individual manufacturers. The true drills have two cutting lips only—single edges in balance. Those with three or with four lips link the drills with the reamers, and are used for finishing holes.

Drill Angles.—Twist-drills are true cutting-tools. The old flat drills were scrapes. The straight-fluted drills used for brass are scrapes. With these exceptions drills are right-handed cutting-tools, only a few for special purposes being made left-handed. The helix angle—that imparted to the flutes (fig. 5, B), corresponds with the top rake of the common single-edged tools. An average is 25°, but in some designs it is as high as 30°. In the "increase" twist-drill the angle changes as the lips are ground, becoming less acute. The exit of the cuttings is facilitated, and the thickness of the web increases. The increased thickness of web provides additional strength to resist torsional stress. A slight disadvantage is the reduction in the cutting angle. The increased twist in drills standardized by different firms varies (fig. 5) from 26° at A to 21° at B, and from 32° at A to 27° at B, at extremes. The angle C of the lips of drills varies only slightly, ranging from 58° to 61°. The usual angle is 59°. The clearance angle or backing-off, D, varies from about 6° to 15°. A usual amount is 12°, but it need not be so large.

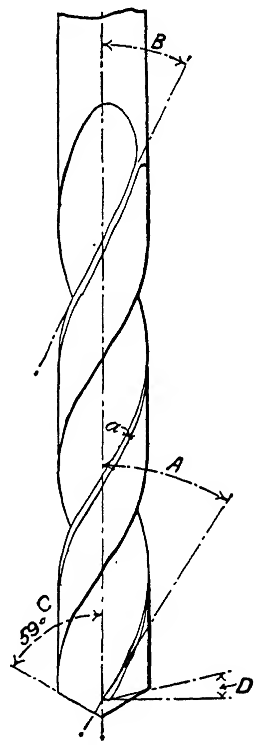


Fig. 5.—Elements of Twist Drill

It should increase from the periphery towards the centre. On this clearance depends the angle which the "chisel edge" or drill point makes with the flat portion of the flute, which is properly 135° (fig. 6, B). If this angle is much larger, as at A, the point is too keen for endurance; if obtuse, as at C, the edge will not cut but will rub only.

The point of a drill must be exactly central with the shank, and the lips of equal length and angle; otherwise the work will not be shared equally, nor will the hole be true to size, nor can it be drilled at maximum speed. Thinning the lips in the larger drills (fig. 7) contributes to efficiency, especially as the tools wear back. Longitudinal clearance is the slight reduction in diameter from lips to shank, which enables the drill to clear itself in its hole. It ranges from 0·00025 to 0·0015 in. per inch in length. Peripheral clearance (fig. 7) is that round the circumference of the drill, starting from the "land" *a* (compare with fig. 5), which backs up the cutting edge and preserves the diameter.

Speeds and Feeds.—The performances of twist-drills vary greatly, the controlling conditions being the quality of the drill, the degree of accuracy of the clearances, the care exercised in grinding, the nature and the amount

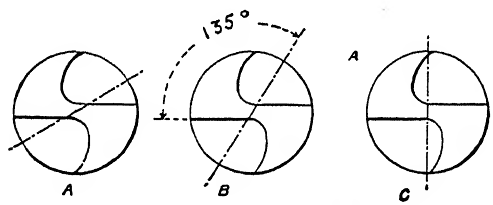


Fig. 6.—Effect of Angle on Chisel Edge or Drill Point

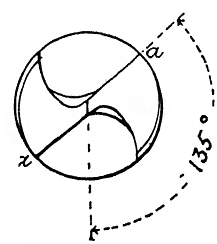


Fig. 7.—End View of Drill

of the lubricant used, the build of the drilling machine, and the mass of the work being drilled. Published tables of performances afford but a general guide, to be accepted with caution. These performances may be exceeded by as much as 100 per cent in exceptionally favourable conditions.

Speeds are usually stated in terms of carbon-steel drills, to be doubled when tools of high-speed steel are used. Peripheral speeds are stated per minute. Average speeds are: for cast steel, 20 to 30 ft. per minute; tool steel, 30 ft.; malleable cast iron, 45 ft.; cast iron, 40 to 50 ft.; brass and bronze, from 60 to 200 ft. per minute. Feeds of from 0·004 to 0·007 in. per revolution are employed for ½-in. drills, increased to from 0·005 to 0·015 in. for those of larger sizes. Generally it is better to increase speeds than feeds.

Lubrication.—The efficiency of a drill depends on proper lubrication more than on any other factor. Generally soda water, soapy water, or emulsion are used, cast iron and brass being the only substances which are drilled dry. Many recipes exist for making up an efficient lubricant, and results are so largely dependent on an abundant supply of the lubricant being provided, that a good many drills, especially those used in turret work, have oil passages through which the lubricant is forced under pressure to the lips. Sometimes oil grooves are formed within the body of the drill, a more satisfactory method than letting tubes into grooves cut around the periphery between the flutes. Such grooves provide ample room for the escape of the chips. Drills with internal tubes are fixed in a turret,

and the work revolves. A cup is screwed into the shank to receive the connection from the oil supply, this connection being usually a flexible pipe.

Twisted Twist-drills.—These are being used in increasing numbers in preference to those in which the flutes are cut by milling. The demands of high-speed work are partly responsible for this design, which is a return to the primitive twist-drills made by twisting a flat bar of steel.

Drill Shanks.—These are standardized both for tapered and parallel shanks. The tapered shank is used with drill sockets, and the second when the drill is held in a chuck or in a turret. There are seven sizes of Morse tapers. One size can only be used for a small range of drill diameters differing by a few eighths of an inch. Adapter sleeves or sockets are then employed, the first for shanks larger than a machine-spindle takes, the second for those of smaller sizes.

GROUP III

Boring-tools.—Boring is distinguished from drilling not precisely because bored holes are usually larger than those that are drilled, but the term signifies the enlargement of a hole which has been already "drilled". Though drilling may be done up to 5 or 6 in., and boring so small as 2 or 3 in. diameter, yet the latter operation is mostly associated with holes that range, say, from about 3 in. to 20 or 30 ft.

Boring-cutters.—The single-edged lathe boring-tool is the type on which all boring-cutters are designed. The single cutter is retained in many cases for roughing. The lathe tool itself has but a limited use in the boring practice of to-day. The solid shank of the tool is a cantilever that chatters if it overhangs much, or if the pressure of the single cut is unbalanced. For long holes two or more cutters in balance are used, either inserted in slotted bars or carried in heads, which are either fixed or are fed along their bars. Different shapes and cutting angles may be used for roughing and for finishing, but frequently no difference is made. In minor details the tools follow the usual practice in tool design which has already been described. The boring-tool is a tool point of an expensive but hard steel, which is gripped in a bar or holder of common material.

Cutters in Bars.—Only the smaller holes are bored with cutters that fit in slots in bars. They are single or double, and are differently secured. A wedge is common (fig. 8) but is liable to shift, so is a round tapered pin, flattened on the side next the cutter (fig. 9). Neither alone would provide for setting the cutter to exact radius, which must be done by gently tapping. Many single- and double-ended cutters are therefore "self-centred" with a notch fitting over the diameter of the bar (figs. 8, 9, 10), and then they cannot shift. Single cutters are adjusted radially with light hammer-taps, and are then tightened with set-screws (figs. 11 and 14). They may be set with a grub-screw at the rear, and clamped with a set-screw (fig. 12). A very common method is that in fig. 13, where the head of a cheese-head screw entering a notch in the shank of the cutter adjusts it finely. Another method applied to double cutters is shown in fig. 15. A grub-screw with a conical

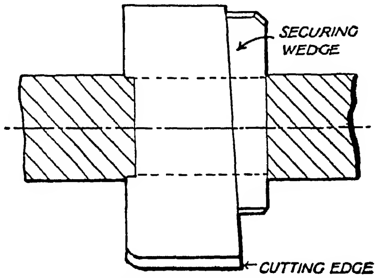


Fig. 8.—Single-ended Self-centring Cutter secured with Wedge. Longitudinal Sectional Elevation.

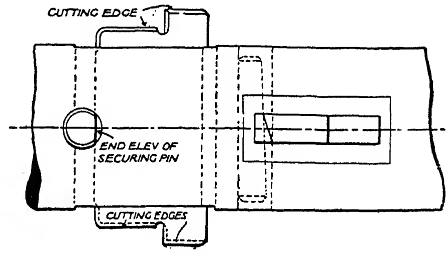


Fig. 9.—Double-ended Self-centring Cutters secured with Tapered Pins

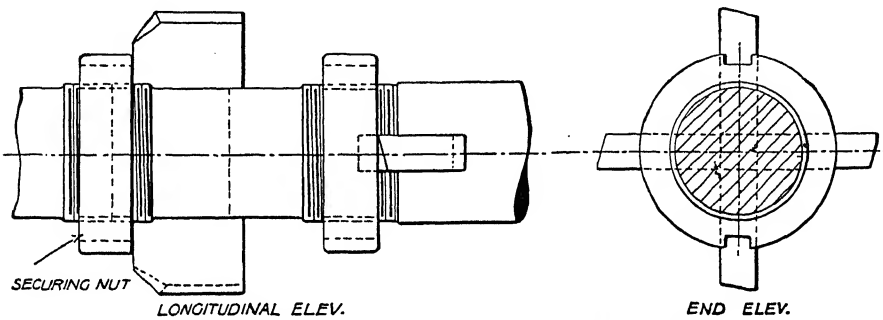


Fig. 10.—Double-ended Self-centring Cutters secured with Nuts

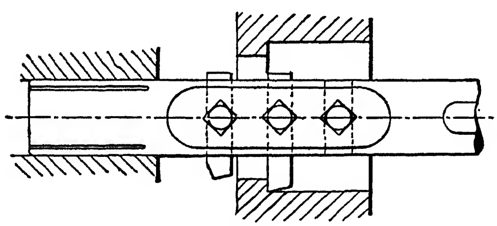
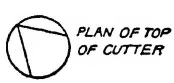


Fig. 11



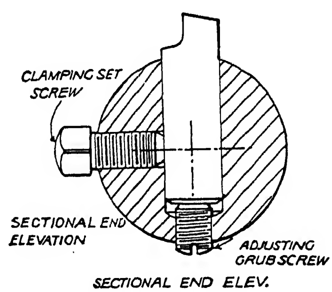


Fig 12.—Single-ended Cutter adjusted with Grub-screw

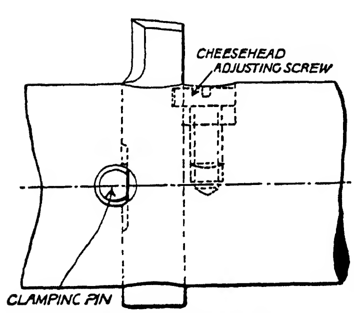


Fig. 13.—Single-ended Cutter adjusted with Cheese-head Screw and Clamped with Tapered Pin

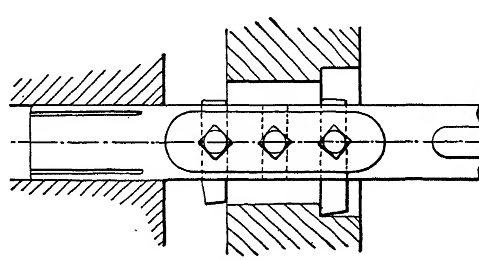


Fig. 14

Figs. 11 and 14.—Examples of Two Single-ended Cutters boring at one time

point moves the two cutters outwards simultaneously, after which they are pinched with the set-screws inserted from the front. Variations made in these elementary fastenings are numerous.

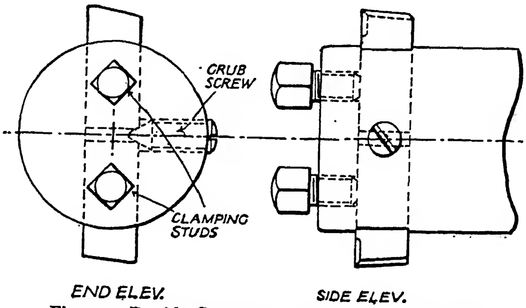


Fig. 15.—Double Cutters expanded with Conical-ended Grub-screw

Pilots are employed to centre and steady the action of cutters. A pilot may enter a bush in the table of a machine or receive guidance from a hole already bored. The method is very common in turret lathe work. Some preceding figures show multiple-

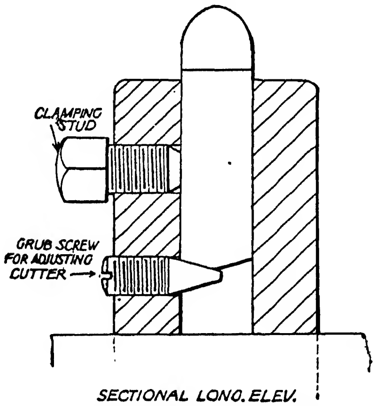


Fig. 16.—Round-nosed Cutter adjusted and clamped in Boring Head

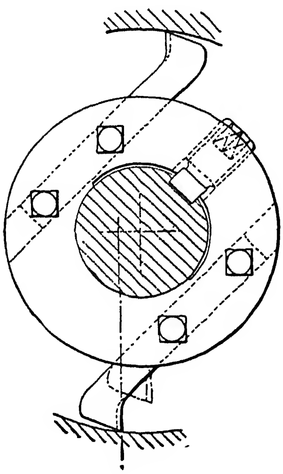


Fig. 17

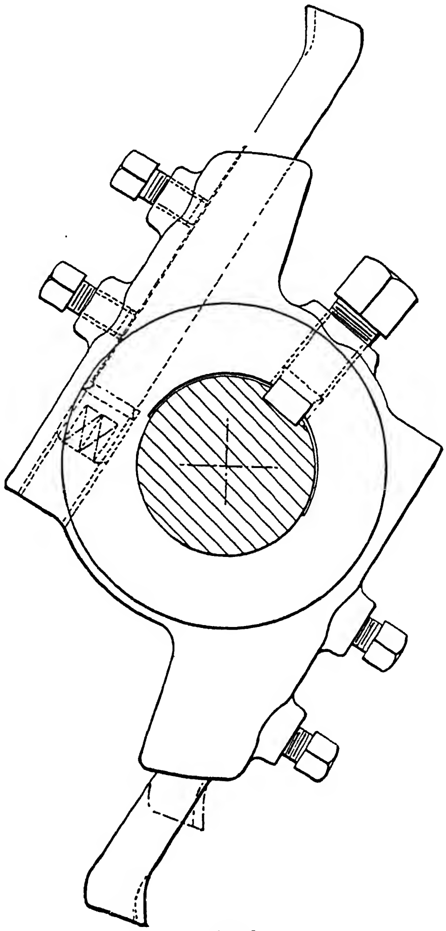


Fig. 18

Richards' Cutters in Boring Heads

cutting. In fig. 9 shouldered cutters are seen, one for roughing the other for finishing, each being secured with a tapered pin. In fig. 10 two cutters are secured with circular nuts that bear against their faces. In fig. 11 provision is made for three cutters in a bar, two slots being occupied; in fig. 14 a similar provision is made. Counter-bores are tools that produce shouldered recesses in holes already bored. They are centred and steadied with pilots, often with provision for changing pilots.

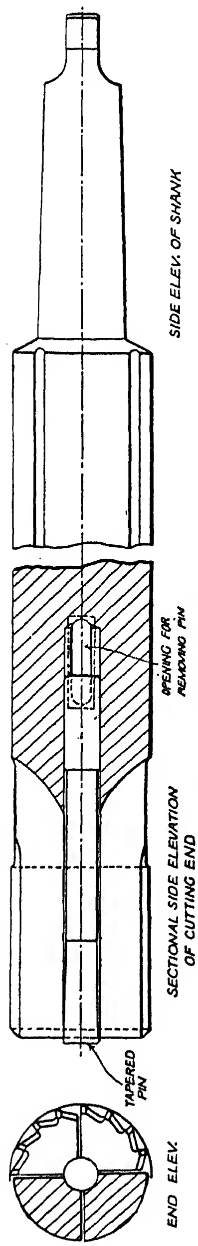


Fig. 19.—Rose Reamer Cutting on End. Expanded with tapered plug

Cutters in Heads.—These are either flat- or round-nose tools (fig. 16) set out with a conical screw and clamped. Figs. 17 and 18 show two of the best methods. The tools being set diagonally cut sweetly. A large range of adjustment is provided for, and the set-screws clamp the cutters securely. The heads fit easily on the bars over half the bore only, and are held securely with set-screws.

GROUP IV

Reamers.—A reamer is used to finish accurately a hole previously drilled, since no drill leaves a hole correct to fine limits or perfectly straight. Though the reamer removes an exceedingly minute amount, two passages with tools of different sizes are often necessary for the finest tolerances. The reamer has many cutting-blades which counterbalance each other. The old D-bit and the rose reamer (fig. 19) cut by their leading edges; present-day reamers cut with the whole length of their blades. The ends are slightly tapered to enable them to enter easily. The blades are often spaced irregularly in order to prevent chatter and risk of " cornering ", due to the fact that if blades are pitched equally they come round to exactly the same place in each revolution, so that any initial inaccuracy will be perpetuated. But the evil is lessened by imparting a small amount of clearance. Blades are straight, or spiral; in the latter the spiral should run contrary to the cutting edge in order to avoid the tendency of the reamer to " draw " into the hole. Reamers are either solid with shanks, or are shells. They are parallel, or tapered. They are made with blades solid, or adjustable (fig. 19).

Clearances.—Though a reamer is a scraping tool—the faces of the teeth being disposed radially—it will not operate well unless suitable clearances are provided. A very slight longitudinal clearance is necessary

as in the twist-drills, the tool tapering towards the shank. This prevents the rear end from rubbing in the hole. End clearance on the lips of the teeth enables the tool to start the cut sweetly. The side or radial clearance produces a smooth and true surface. Without this the edges would rub hard and not cut at all, and the hole would not be true. Generally the radial clearance is a straight face, lying at an angle greater than that of the actual cutting edge, which is very narrow, like the " land " on a drill. The edge so formed lasts longer than it would if it were left keen.

Flutes.—The sectional forms of flutes vary. They may be straight, concave, or convex, the first being most common as it is more readily reground than the others. The flutes of tapered reamers are straight, or spiral in the longitudinal direction. When used for roughing, the flutes are either notched or they have a spiral groove running all round the teeth to break up the chips (fig. 20). Some of the chucking reamers have straight flutes, while a good many have three-grooved spirals with oil grooves for the passage of the lubricant. All the solid reamers have shanks either parallel or tapered to standards. Shell reamers fit on arbors, and are only used for the larger holes.

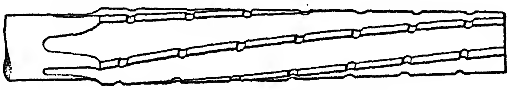


Fig. 20.—Tapered Roughing Reamer

Left hand not to pull in. Serrated spirally to break up chips.

Floating Reamers. — These are used in some of the finest operations. They accommodate themselves to the holes which they finish. They may float perpendicularly and at an angle. They are employed extensively in turret work, for which special holders are provided.

Adjustable Reamers.—These are in some degree a result of the growth of the limit system of gauging, in which minute differences in the diameters of holes for tight, push, and easy fits have to be made. If solid reamers are made to deal with certain sizes of holes, they lose their dimensions rapidly with regrinding. There are many differences in the details of fitting and adjusting the blades in these tools. They may be classified as follows:—

1. Reamers having a solid body with splits, to be expanded by an internal tapered plug (fig. 19), which is either drawn or thrust inwards with a screw or driven with a hammer. Only a very slight amount of expansion is obtainable with these, but they are suitable for jobs where only fine cuts are required with little variation in size. They are used extensively on turret lathes.

2. In this group, loose blades are fitted in recesses in the body, and expanded by the insertion of packing strips beneath them. The one advantage of this design is that the blades bed solidly on the packing, and that packings of increased thickness can be substituted as the blades become worn. They are also cheap, having few fittings, and they cannot readily be tampered with. Tin-foil is used for packing, the thinnest strips of which measure 0·0005 in. thick. These designs are used in turret lathes.

3. The blades are fitted in recesses, and are expanded with wedges driven beneath them.

4. The blades fit in inclined slots, and are expanded by driving them inwards towards the higher ends, with or without using locking nuts for their retention. The blades are ground in place while the body is mounted on centres.

5. In this group the blades are fitted in inclined slots, and are moved up with nuts coned on the inside to retain the blades, with or without lock nuts. This design is much to be preferred to the last, because the movements imparted to the blades are simultaneous and more precise, and regrinding is not necessary after the setting. Many of the best reamers are made in this way.

6. Blades in slots rest upon a central tapered plug or " cone bolt ", which, being forced inwards, expands all the blades equally. The locking is effected with nuts. In the " Vickers " design the expansion is imparted without longitudinal movement of the blades. In a sub-group the blades are expanded with two cones, reversed, which are drawn towards each other. A large range of diameters can be obtained with these.

7. In some designs an eccentric or cam bolt has a series of cams like very shallow ratchet teeth, which by their partial rotation cause the blades to move outwards.

GROUP V

Milling-cutters.—These have gone through a larger evolutionary growth than any other single group of cutting-tools. They range from ½ in. diameter to several feet; include true cutting as well as scraping teeth; can be used to rough and finish work; and produce not only plane surfaces but combinations of horizontal and vertical faces, and curved and irregular contours.

Teeth, Speeds, Feeds.—Milling-cutters have very little in common with the single-edged cutting-tools, since their teeth operate in quick succession over broad surfaces. In the edge mills taking deep cuts the angles of presentation will change, and the teeth will rub on the leaving edge. Also the chips will become entangled between the teeth and cause friction. The teeth of all the early cutters were pitched too finely to permit of their use as roughing-tools. Coarser pitches are imparted now, and roughing-cutters may be had, but generally the same cutter is employed for both functions. For roughing, the teeth are often notched to break up the chips, and all except the narrowest cutters have spiral teeth which effect a gradual cut. A cutter must not be run at a high speed, since its teeth would become choked with chips, but the feed should be coarse. Feeds have been increased amazingly. They are stated in terms of advance in inches per minute, or in fractions of an inch per revolution of the cutter. A more practical test is the number of cubic inches of material removed per minute. The end mills are more efficient as roughing-tools than the edge cutters are, since there is no change in cutting angles and the chips get away freely. As a

rule the teeth have no front rake, but clearance only, generally with two or three facets, one being the "land" for grinding. Formed teeth are numerous, in which the backs of the teeth are struck from a centre eccentric in relation to the cutter centre. These are reground on the front faces only, and retain their sectional shapes until worn thin. These belong to the profile group, used for gear teeth and allied shapes.

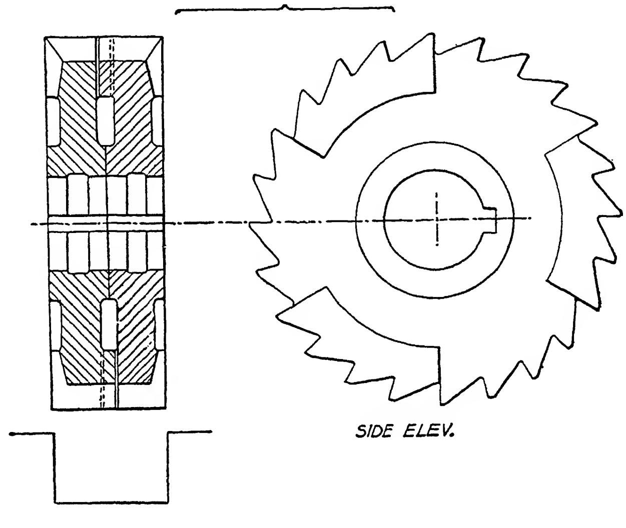


Fig. 21.—Two Interlocking Slotting Cutters clutched so that Teeth overlap and Width can be preserved after Wear

The Forms of Cutters. — These include edge, side, end, and formed cutters, both angular and curved, solid tools and those with inserted teeth.

Edge and Side Mills. — In these (figs. 21, 22) the teeth are cut on the peripheries, and on one or both ends respectively. When cut on both ends they are used for slitting and grooving. The

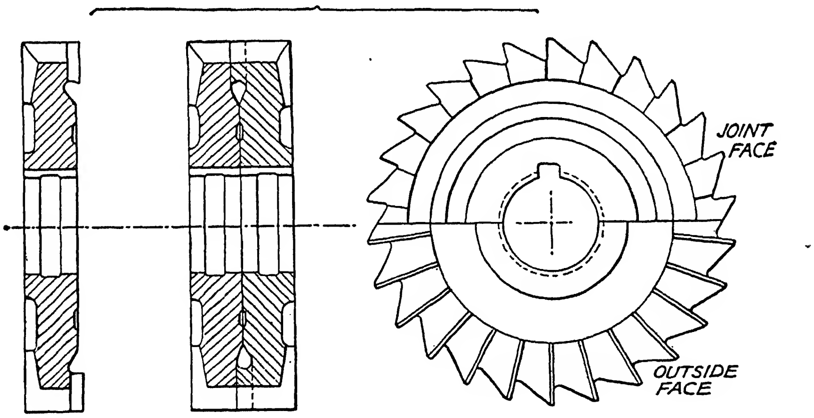


Fig. 22.—Interlocking Cutters in which each Alternate Tooth interlocks

cutters, in figs. 21, 22, have provisions for preserving the width. Edge mills when over 1 in. in diameter are provided with spiral teeth, usually at an angle of 10°, except in some cutters for roughing, in which this angle

is considerably exceeded. Since, as a rule, cutters are used for general service, the speeds, depths of cut, and feeds are varied to enable them to work with efficiency on all materials. Only in the most general terms can these be hinted at. Soft steel can be cut at peripheral speeds of from 90 to 150 ft. per minute; the harder steels from 65 to 75 ft.; cast iron, 80 to 100 ft.; the brasses and bronzes up to 1000 ft. per minute. Depths of cut may range from $\frac{1}{16}$ to $\frac{1}{4}$ in. in one traverse. Feeds, formerly so low as 2 to 3 in. linear feed per minute, are frequently now from 12 to

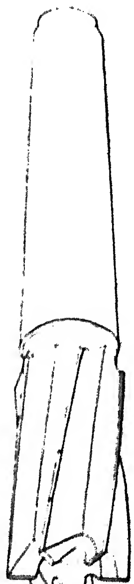


Fig. 23.—End Mill

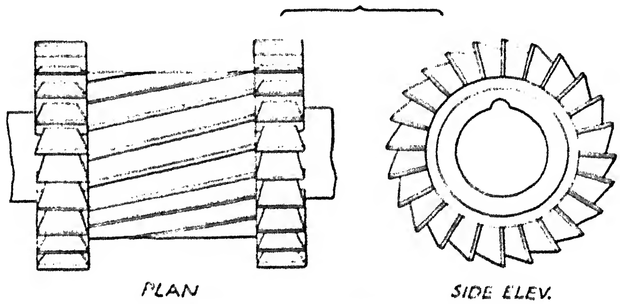


Fig. 24.—Three Cutters in Gang

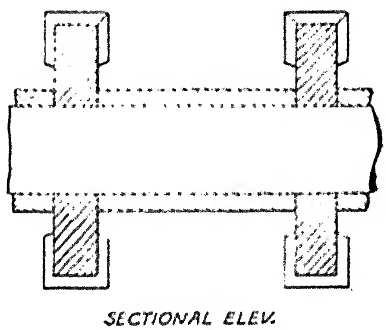


Fig. 25.—Two Cutters in Gang, with Distance-piece

20 in. The metal removed in a minute with a cutter 8 in. wide working on mild steel has amounted to 23 c. in., and on cast iron to 48 c. in.

End Mills.—In these (fig. 23) the end teeth cut, and those on the side smooth the surfaces. The teeth are straight for working on brass, for other materials they are spiral. This provides a cutting rake, or, when the spirals are left-hand, the rake is negative with the tendency to hold the tool back in its spindle. These tools only cut on the inner ends of the teeth in the "centre-cut mills", which have teeth on the inside, so that in these the tool can be sunk vertically to the required depth, and then traversed. End mills are provided with standard taper shanks, or they are shells fitting on arbors.

Form Cutters.—These include various angular shapes for cutting grooves and vee'd edges; the tee-slot cutters; angular cutters for producing the edges of slides; the very numerous shapes employed for grooving concavities; a large group, employed for fluting the drills, reamers, and

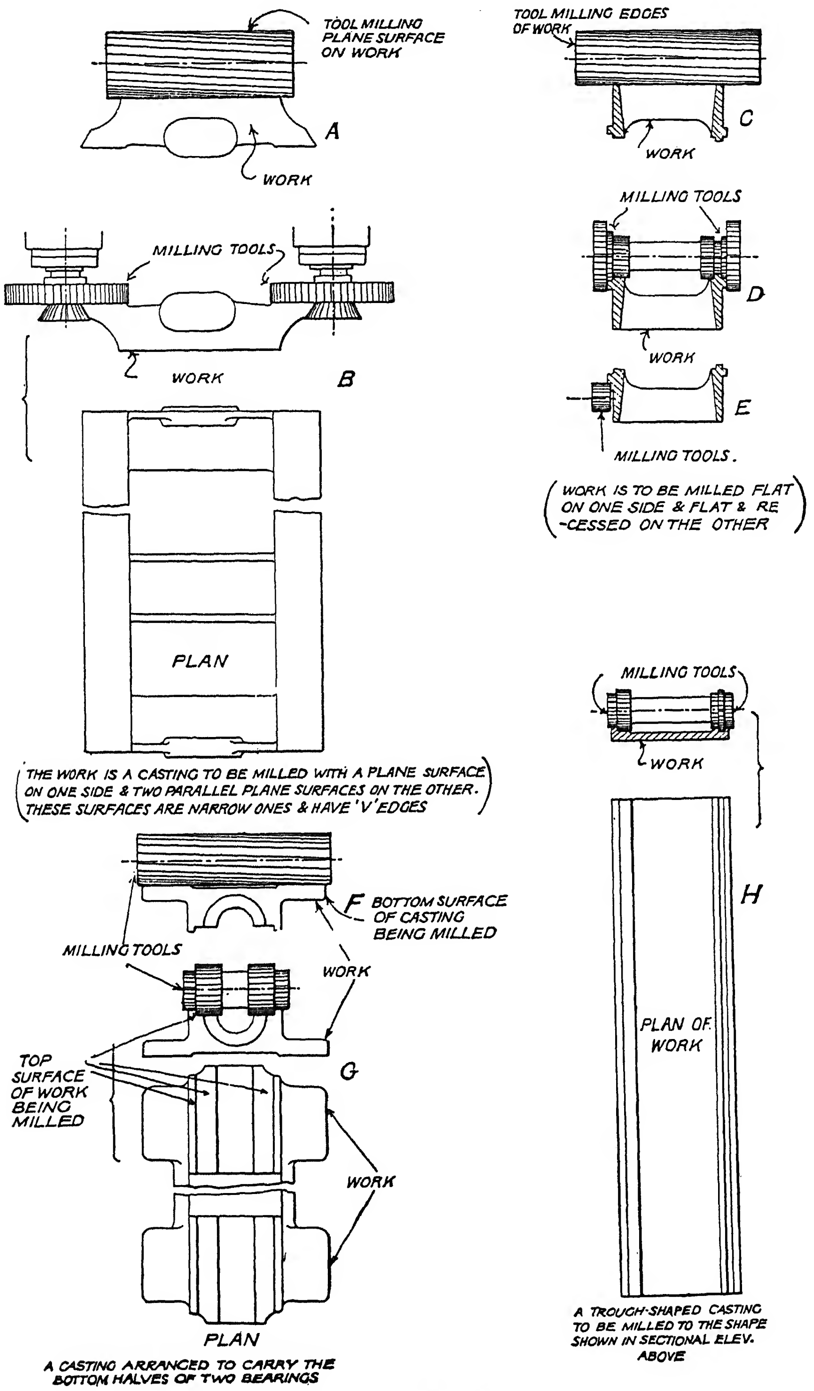


Fig. 26.—Examples of Milling Operations

milling-cutters, and typical of those used for gear teeth. A concave cutter is used for producing beads, and combinations of these and similar outlines are often made for special work.

Gang Cutters.—These, of which figs. 24, 25, 26, 27 are typical, are

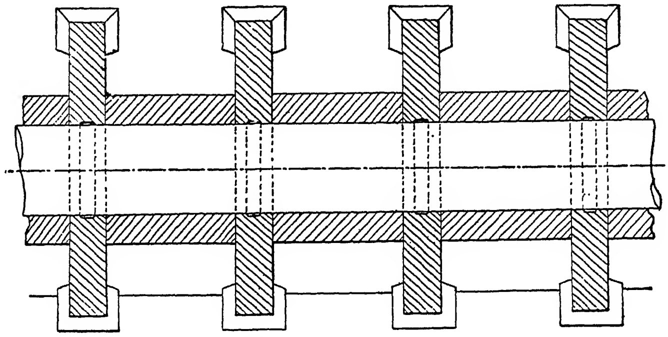


Fig. 27.—Four Cutters in Gang, with Distance-pieces

used extensively on all the horizontal milling machines, but mostly on the plano-millers. Single cutters are built up to suit requirements. Fig. 24 shows three for cutting faces and edges simultaneously. These are frequently interlocked, with provisions for taking up lateral wear. Fig. 25 illustrates two, fig. 27 four on an arbor, with separating distance-pieces. The group (fig. 26) shows various operations. At A an edge mill is tooling the bottom of a bed. At B gang mills are tooling faces and edges. C, D, E show three sets of operations on a bed. At F and G cutters are at work on the bottoms and faces of bearings. H shows the milling of a long strip on five faces.

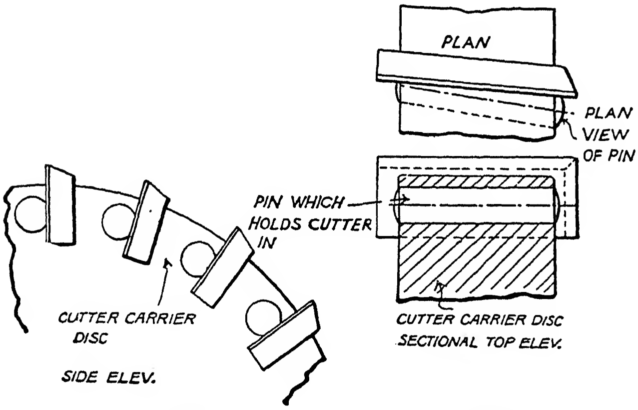


Fig. 28.—Inserted Cutters, set spirally, held with Pins flattened to bear against Cutters

Inserted-tooth Cutters.—When a cutter exceeds a few inches in diameter it cannot be hardened and tempered like the smaller tools. Inserted teeth of high-speed steel are fastened in bodies of cast iron or of mild steel. Cutting points are often identical in shape with the single-edged tools. Teeth are set straight-faced or spirally, and are fastened in many ways. 28 shows spiral blades held with flattened pins. Side cutters are located

with shoulders and held similarly. Roughing-cutters in fig. 29 are each adjusted with a grub-screw and locked with a nut. Cutters are set spirally, and tightened with tapered pins in splits. Wedge bushings and screws are

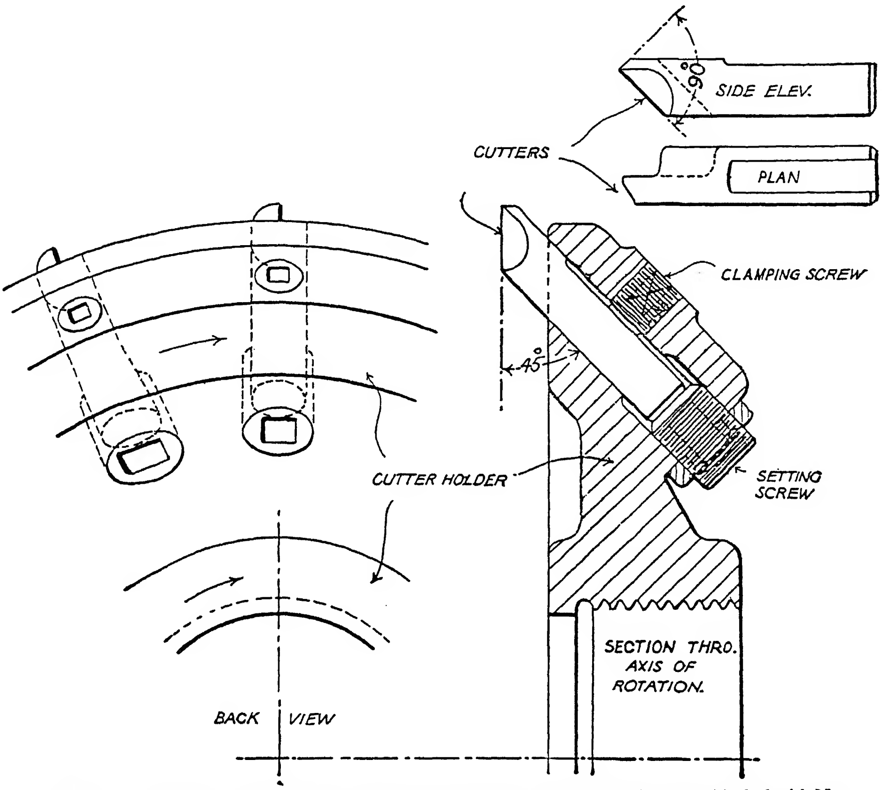


Fig. 29.—" Wrigley " High-speed Cutters for Aluminium, adjusted with Screw and locked with Nut

used for tightening. Many of the heads with inserted cutters are several feet in diameter.

GROUP VI

Grinding Wheels.—The old term " emery " wheels applied to this group has long been abandoned, since emery is employed to a limited and ever-lessening extent, having been replaced by more effective grinding materials.

Emery and Corundum.—The difference between these is one of purity. Alumina is the chief constituent of each. Corundum contains a higher proportion of alumina than emery, and its grains split, leaving sharp edges; while emery wears smoothly, with a glazed surface. Both materials are impregnated with oxide of iron, which, when present in large quantities, reduces the cutting capacity. On the other hand, emery wheels produce a high finish.

Carbide of Silicon Abrasives.—These are prepared in electric

furnaces from coke and sand. These abrasives include carborundum, crystolon, carbolite, corbolon, carbowalt, and corex.

Aluminous Abrasives.—These are prepared in electric arc furnaces from bauxite, a clay that contains a high percentage of aluminium oxide. It is a soft light-yellow earth, and is the purest form of aluminium oxide found. Only in the electric furnace can the nearly pure alundum be separated from the foreign matters present in the earth. The abrasives obtained in this way are: alundum, alowalt, aloxite, borocarbone, carbo-alumina, corowalt, oxaluma, and rex.

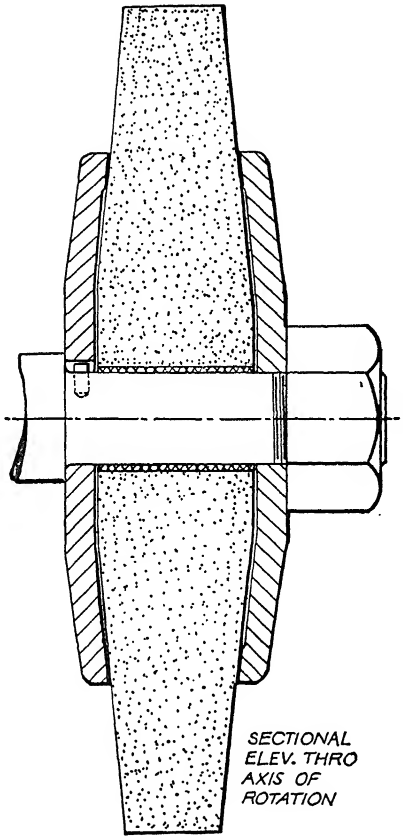


Fig. 30.—Edge Grinding Wheel with Bevelled Safety Flanges

Applications. — Although several of these abrasives are employed for similar purposes, yet some are more suited to certain duties than others. Broadly, the wheels used for materials of low tensile strength, such as cast iron, brass, and aluminium, are not employed for the steels which have high tensile strength. In general a carbide of silicon abrasive is used for the first, and an aluminium oxide abrasive for the second.

Grain or Grit. — The number that designates the grain signifies the number of meshes to the linear inch in the grating forming the bottom of a sieve, through which the grains will pass. The numbers in common use range from about 20 to 60. Usually all the grains in a wheel are of the same size, but " combination " wheels are used, with the object of enabling them to cut fast and finish smoothly, and so avoid a finish grinding with a second wheel.

Grade or Bond.—The efficiency of a grinding wheel for a definite duty depends on what kind of material is employed to cement the grains together. Wheels are " hard " when the grains are not easily dislodged from their matrix, " soft " when they are readily torn out. But the size of the grains has a modifying influence, since a wheel with the same bond is harder if the grains are fine than if they are coarse. Generally a harder wheel will be used on soft steel than on the same steel if hardened. The harder the material is, the softer the wheel should be. The reason is that a hard material will blunt the grains more quickly than a soft one, and therefore they should be torn out more rapidly to allow fresh grains to come into action. An exception occurs in

the brasses, which require a soft wheel in order to prevent clogging or glazing of the wheel with particles of metal.

Bonds.—The three bonds commonly employed in the order of their importance are: the vitrified, the silicate, and the elastic. The first is composed of clays, properly a pure grade of kaolin. The wheels are moulded and subjected to a prolonged heat to partially fuse the bond. The wheels are of a reddish-brown colour, are very porous and free-cutting, and are not affected by water, oils, or temperature, and the bond is hard.

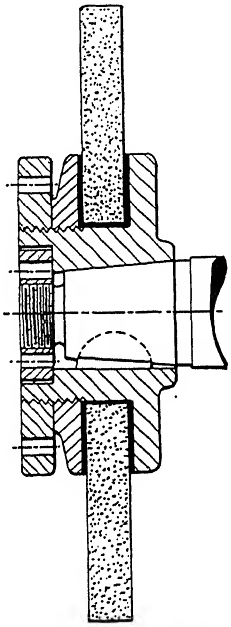


Fig. 31.—Edge Wheel mounted permanently on Flanges for accurate Replacement and Wheel-changing on Mandrel

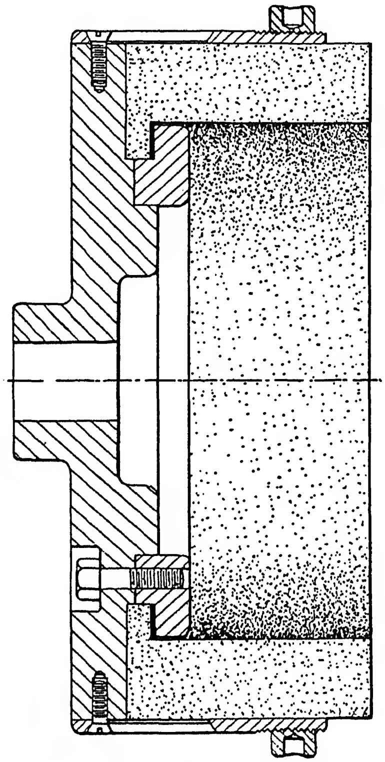


Fig. 32.—Cup Wheel Mounting, with Safety Ring

But the risks of cracking do not permit of making these wheels beyond about 30 in. diameter. These are suitable for general grinding. For the silicate bond the silicate of soda is chiefly used. The process is less prolonged than that for vitrified wheels, and larger sizes can be manufactured. These are not used much for cylindrical grinding; their function is that of wet grinding of tools. The elastic wheels are mostly bonded with shellac. Vulcanite wheels are bonded with vulcanized rubber. Both can be made very thin, and be run in water. Vulcanite wheels can be used with oil or caustic soda; elastic wheels cannot. These are made thin for cutting off materials, for grinding saws, and sharpening cutters.

Wheel Shapes and Mountings.—Fig 30 shows an edge wheel, used for cylindrical grinding, with one method of mounting. The flanges are

dished to suit the section of the wheel, and they only bear against it with annular seatings, which do not tend to crush the wheel, and, if it should fracture, the pieces are prevented from flying off. Wheels of parallel thickness are also gripped with annular contact. Another essential is that the wheels fit loosely on their arbors and tight only in the flanges, to avoid risk of their being burst. Fig. 31 illustrates a wheel gripped with washers of leather, rubber, or cardboard. But the principal feature is that the wheel is mounted permanently with a screwed flange, to be removed from and replaced bodily on the tapered end of its arbor, where it is held with a circular nut. Fig. 32 shows a face wheel. The mounting includes an encircling safety ring, which is set back as the wheel wears. In the Blanchard wheel, used on the firm's vertical-spindle machines, the principal feature is the provision of holes in the flange to direct water to the face of the wheel.

CHAPTER III

The Essentials of Economical Machining

DIVISION I

Lubrication.—The efficiency of cutting-tools depends on the lubrication and the cooling of the tool point, and of the surface of the work being cut. Cast iron and brass are usually excepted. Formerly the chief attention was directed to the cooling of the tool; now the view-point is changed, consequent on the increased severity of cutting, with the more rapid generation of heat. Instead of the drip-can, the cooling liquid is delivered in a stream, frequently under pressure, and directed with pipe nozzles or spreaders all over the surfaces being cut.

Cooling Fluids.—With these changed views the practice has undergone great changes. Special lubricants are now used for certain classes of heavy, medium, and light work. As of old the best all-round lubricant is lard oil, but the high cost of it handicaps its general use. The best substitutes contain a mineral oil with a certain quantity of lard, and are termed "mineral lard oils". The proportions of lard are varied for different kinds of work. Soda or potash mixed with a mineral lard oil forms soap. The soap holds the oil in suspension, and prevents it from floating on the surface.

Distribution and Recovery.—Instead of the drip-can a system of supply pipes is laid down in modern shops, and each machine is provided with its own particular equipment for distribution through jets or nozzles, with means for the collection and return of the liquid. In some cases a gravity supply is installed. A feed tank is placed in the roof, and the machines drain to a sump below the floor. More often now the cooling fluid is delivered by means of a pump. In a few shops different groups of

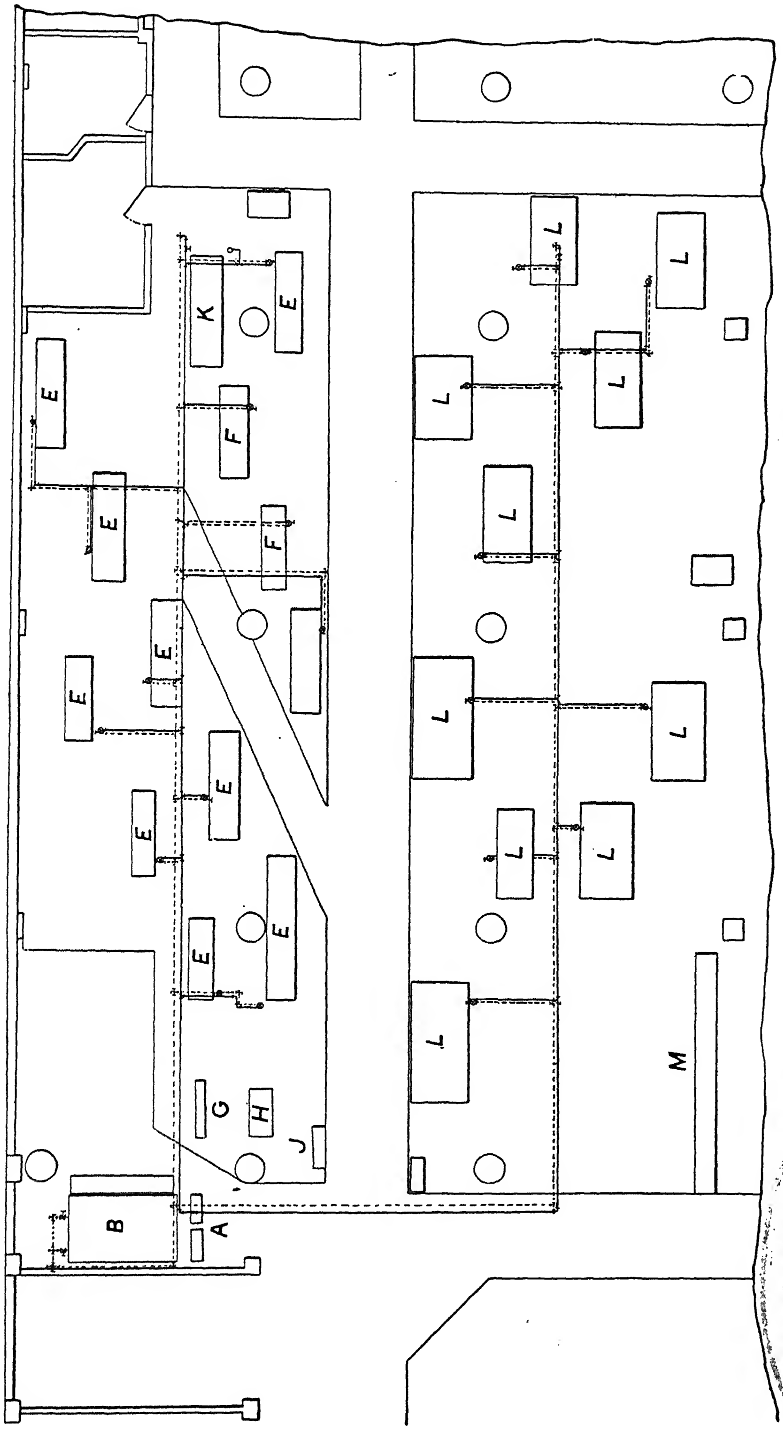
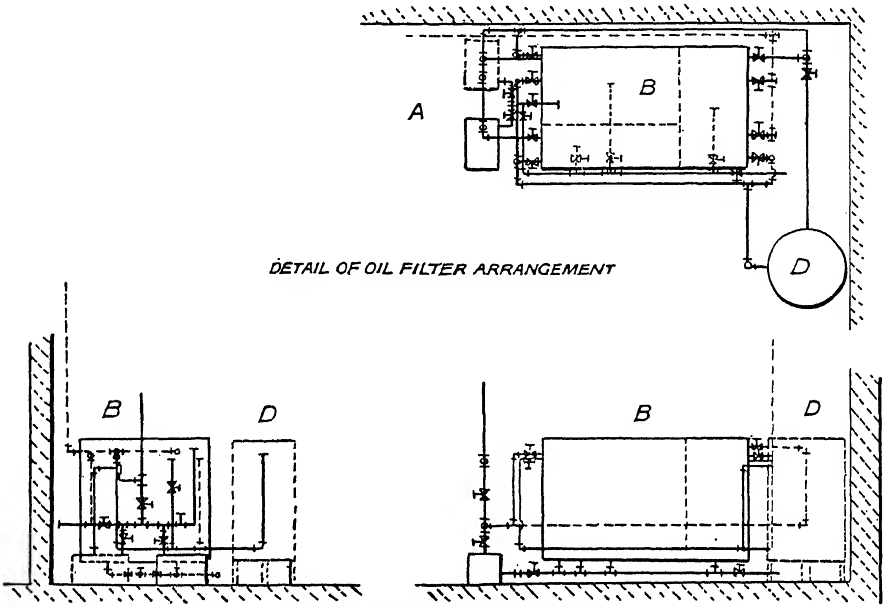


Fig. 33.—System of Oil Pipes and Filters for Lubricating *Cutting-tools*, installed in American Tool Works

machines are provided with special supplies of cooling fluid particularly suited to the kind of work done in them.

The floods of lubricant supplied are mostly recovered. For the collection of liquids at the machines, tanks or trays are now fitted. In these the lubricant is drained through a grating, leaving the chips and dirt behind. At



Details of Filter for Lubricating Oil

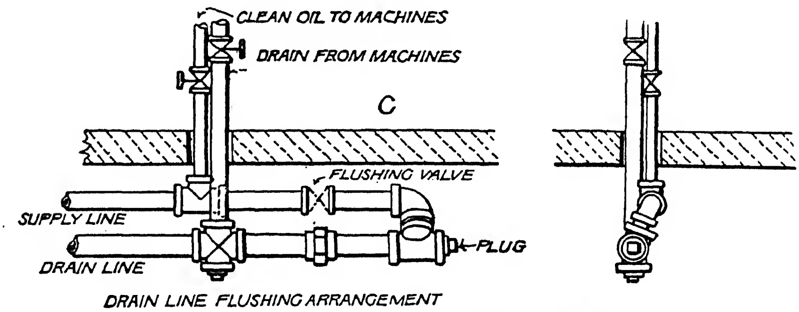


Fig. 34.—Enlarged Details of Oil Piping System

intervals the liquid is drawn off to be treated in centrifugal machines, or in filters. Fig. 33 is an illustration of the arrangement of oil piping and a filtering system in the American Tool Works, as laid down by the Richardson-Phenix Company, of Milwaukee, Wis., U.S.A. The full lines show the supply pipes for clean oil; the dotted lines, the return drain pipes. The first, starting from the centrifugal pumps, A, diminish from $2\frac{1}{2}$-in. bore to $\frac{3}{4}$-in. bore at their terminations. The drain pipes increase from 1-in. to 3-in. bore where they terminate at the filter B, which is shown in detail in fig. 34.

The drain line flushing arrangement is shown at C, fig. 34, the object of which is to prevent sediment from accumulating and impeding the free movement of the liquid. The oil is sterilized in the vessel D before being filtered. The machines are lettered as follows: fig. 33, E indicates flat urret lathes of various sizes; F, lathes; G is a centring-machine; H, one for testing; J, one for cutting off stock; K, a Jones & Lamson lathe; L, various automatics; M, is a stock rack.

DIVISION II

Speeds and Feeds.—The speed of a cutting-tool, relatively to that of the piece of work on which it operates, irrespective of whether the tool or the work moves, is expressed by the number of linear or peripheral feet passed through per minute by the tool or the work. The feed in turning and planing is the lateral distance traversed between each cut; in drills and face-milling cutters it is the depth of penetration estimated in some minute fractional part of an inch per revolution of the tool; in edge-milling cutters it is stated usually as the linear distance travelled by the work under the cutter per minute; in grinding wheels it is the depth of cut given by each setting-in of the wheel.

There are standard speeds memorized in the shops, just as there are standard tool angles for different materials. But they are more honoured in the breach than in the observance, and are exceeded in favourable conditions. There are no commonly recognized feeds. But, with the increasing stiffness of machine-tools and with improved lubrication and suitable tool angles, feeds are generally very much coarser than of old, notably in high-speed turning, in drilling, and in milling.

Relations of Speeds and Feeds.—There is no hard-and-fast rule as to whether high speeds and fine feeds, or low speeds and coarse feeds are preferable. In drills, for instance, it is more economical to increase speed than feed. In edge-milling cutters the best results are secured by low speed with coarse feed. In turning and planing, high speeds and coarse feeds may go on simultaneously. The old speeds for carbon tools were: cast iron, from 15 to 20 ft. per minute; steels, from 15 to 30 ft.; wrought iron, from 25 to 40 ft.; and brass from 50 to 100 ft. These are now generally exceeded, except in the harder qualities, and tools of high-speed steel will cut at double these rates. But any general statements can only be approximate, since results are controlled by many variables, as tool angles, depths of cut, rate of feed, grade of material, the rigidity of the machine, and the volume of lubrication—often the largest factor of all. Because of these facts, no ratios of speeds and feeds could be tabulated that would be of any general value.

Depth of Cut.—This may range from 0·001 in. in grinding wheels to 1 in. in cutting tools. An increase in depth of cut involves a reduction in cutting speed and feed, because the capacity of a tool is measured by the area of cut plus the feed. Heavy cuts at slow speeds are more economical than light cuts at high speeds. But the horse-power required is greater,

which explains why machine-tools at the present time take much more power to drive than their immediate predecessors did. The weight of material removed in a given time is the real test of the cutting capacity of a tool. The endurance of a tool is the true measure of its efficiency, since one that has to be reground at short intervals is not economical. A single-edged tool should endure for at least an hour, while milling-cutters and those set up in boxes for turret-lathe work should last for a day or more. The longer the time occupied in regrinding and in resetting, the stronger is the reason for maintaining the endurance of the edges.

DIVISION III

Setting and Securing Work.—Broadly there are two methods employed for holding articles to be tooled. In one the piece is gripped either directly on the work table of the machine or in a chuck, or on an arbor, with the help of appliances that are in common use for a multitude of various jobs. Here in general the pieces are set and held singly even though many are identical in shape and dimensions. In the other method they are not attached directly to the table or other work-holding element, but to an intermediate appliance, the fixture, or to special adaptations of chucks or arbors. The first is the older practice, necessarily retained for all classes of work that are not highly repetitive. The second is the later method, essential to and inseparable from mass production, and an interchangeable system.

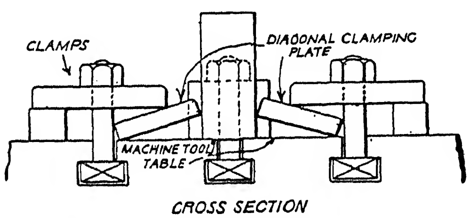


Fig. 35.—Clamping Plates set Diagonally

Work held on Tables.—This chiefly concerns the planer, shaper, and slotter groups, and the drills, boring machines, and allied forms. The feature common to all is the level table, provided with grooves of tee-section to receive the bolt heads for clamping work. The grooves are also used to hold stops, angle plates, vee blocks, and so on.

The surface of the table provides the accurate datum for ensuring that the clamped work will occupy its correct relation to the cutting-tool. Hence the first care is to get the work to bed truly on the table. When practicable it is well to take a rough cut off one surface of the work in order to secure contact. If this cannot be done, then a rough surface must be packed carefully with wedges where it is out of contact with the table, or the clamping bolts will pull and spring the work, and it will not be true when the machining is done and the pressure of the bolts released. Though the effect is more pronounced in thin pieces, it is present in all except the most massive chunks. Hence, a safe rule is never to tighten a bolt except in opposition to a machined surface, or, with a rough surface, near a packing.

Thin, and Substantial Articles.—When dealing with very flimsy

pieces, it is not permissible to clamp directly on their upper surfaces. Lateral pressure is adopted in such cases, and also for those where the upper surfaces have to be machined all over. The clamps are better if set diagonally (fig. 35) to exercise a downward pressure. Often it is necessary to set a stop against one end of the work in the line of direction of the cutting-tool in order to prevent the occurrence of slip by reason of the pressure in the longitudinal direction. For holding substantial pieces, direct clamping is adopted. But, since tall bolts are apt to be unstable under the stress of heavy cutting, advantage is taken of the presence of suitable lower sections on which to bed the clamps. These may be stout flanges, bosses, bores, or recessed portions, to be utilized by the judgment of the machinist.

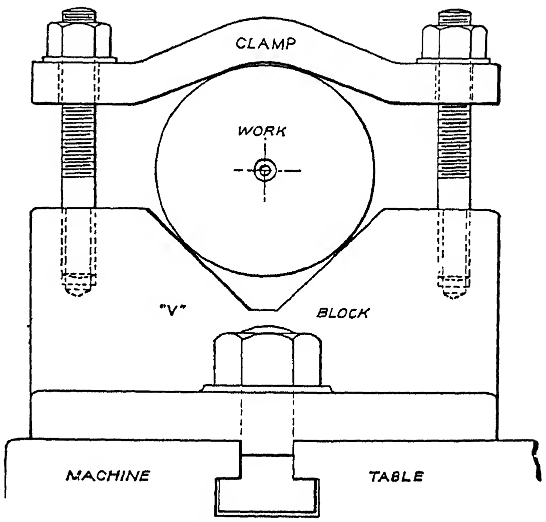


Fig. 36.—Large Vee Block and Vee'd Clamp

Cylindrical and Bored Work.—This is located and held in vee blocks, which ensure parallelism of the work with the table. Parallel shafts

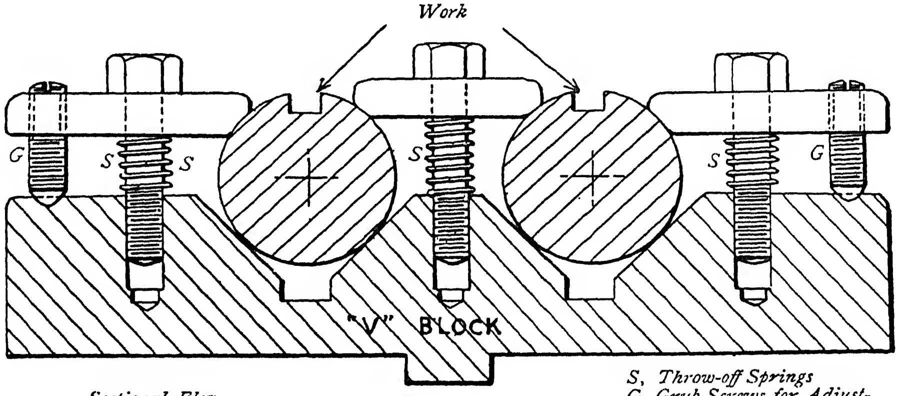


Fig. 37.—Vee Blocks for Two Shafts, Clamp Plates adjusted with Grub-screws and thrown off with Springs

and tubular portions of castings when located in vees of equal heights will lie parallel with the table. If shafts are put through holes, and laid in vees, the holes will be parallel. The clamps are variously set, according to outlines, dimensions, and the avoidance of portions to be machined.

In most cases the clamps are vee'd in the grip (fig. 36), to ensure a better hold and to shorten the length of the upstanding bolts.

In fig. 37 a vee block is made specially to hold two shafts, to be key-grooved. The outer clamp plates are made to grip the shafts by the tightening of their grub-screws. A useful provision is included, that of the insertion of coiled springs surrounding the bolts, which throw the clamps clear when the grip is slackened.

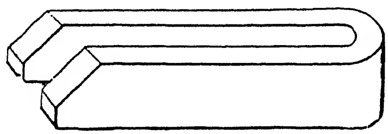


Fig. 38.—U- or Hair-pin Clamp

Clamping Plates and Packing.—In general these are distinct and separate, the packing being of wood or metal, cut or selected to suit the height of the clamp plates, the latter being kept strictly horizontal. But as work becomes more repetitive the packing is included with the plate to avoid the loss of time involved in handling loose pieces. Clamps have the form of plates, with slotted holes for bolts, or they are of U shape (fig. 38), which affords a larger range of longitudinal adjustment. They are single, or double, the latter to grip adjacent pieces, in which case packing is not required (fig. 37). In this figure the grub-screws fulfil the function of packing. Small screw jacks often serve as adjustable packing. Another group comprises stepped blocks (fig. 39) to give a range of heights.

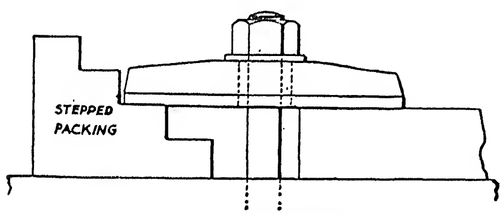


Fig. 39.—Stepped Packing

Intermediate Attachments.—Many articles have to be fastened to an angle plate instead of directly on the table. This occurs when a piece must have faces machined at right angles, and when the shape is such that it cannot be held on the table without involving awkward packing-up. Faces that occur at other than right angles are dealt with on tilting or swivelling angle plates. Articles of another kind have to be held on machine centres, carried on a machine table. These are used when machining has to be done in angular relations, such as the machined splined grooves in shafts, and in the drilling of holes from various angles. The work is carried on the centres directly, or on an arbor, and the angular positions are set with pins in holes, or latches in recesses, or by means of a circle divided into degrees. The machine vice is admirably suited for holding small articles. It is used chiefly on the shaper, the milling, and drilling machines, and occurs in many forms, to hold parallel or bevelled pieces, to be machined in parallel or angular relations.

DIVISION IV

Jigs and Fixtures.—A jig is an appliance that guides and controls the location of a tool relatively to the work. A fixture is one that locates and secures the work being tooled. The one may be used without the other. If both are employed, they may be entirely separate and distinct, or be combined in one jig-fixture. Both are intimately associated with the standardization and interchangeability of the parts of machines and mechanisms. They eliminate the need for the tedious, separate lining-off and setting of single pieces, and they lessen the errors that occur in machining.

The Jig.—The original of the present-day jigs in their myriad forms was the drilling templet. The majority of jigs are employed still in the work of drilling and boring. In these the bushes are the vital elements, because on their accuracy the correctness of results depends. They are made of steel, hardened and ground, and provision is made for their ready renewal when they become worn by the friction of drills, reamers, and boring-tools.

The simplest bushes are those which are a press fit in the jig. These are only removed when worn out. A better and more accurate method is to have a permanent lining bush to receive a removable one, the two being fitted by grinding. It is well to make bushes with a collar, to prevent them being pushed down too far in their holes. The edge of the bore where the drill enters is slightly convex. Bushes are sometimes screwed in where they must come into contact with the work. Lockings are employed to prevent bushes from turning. A set-screw or a button is fitted to a slot in the collar, or flats are made on collars of adjacent bushes. A bush may contain two or more holes in close proximity. A simple bush is slightly longer than its bore. A small bush will be of greater length, relatively, than one of large diameter. All dimensions are usually standardized in shops where the system is a permanent one, and each size of bush has its own reference letter or figure.

Fixtures.—The employment of fixtures is the only alternative to the practice of bolting articles directly to the tables of machine-tools. This is a tedious process in the case of those of awkward shapes that require packing, and have to be set by careful measurement. This often occupies more time than the actual machining does, and distortion is liable to occur. From the point of view of interchangeability it is hardly possible to set two pieces precisely alike. The fixture is designed both to locate and to hold the article, or often several, in the same exact position, so that each article will be machined in the same way.

In good designs provisions are made to lessen the time occupied in setting and in holding to a minimum. Often, as a result of high economies, it becomes necessary to duplicate fixtures. One is unloaded and reloaded while the other is on the machine-tool.

Jig-fixtures.—The highest developments are reached when the fixture and jig are combined. The jig is generally hinged in some way to

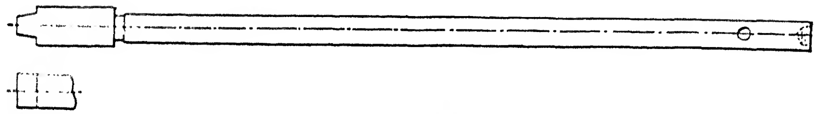


Fig. 40.—Plunger for Sensitive Feed Lever

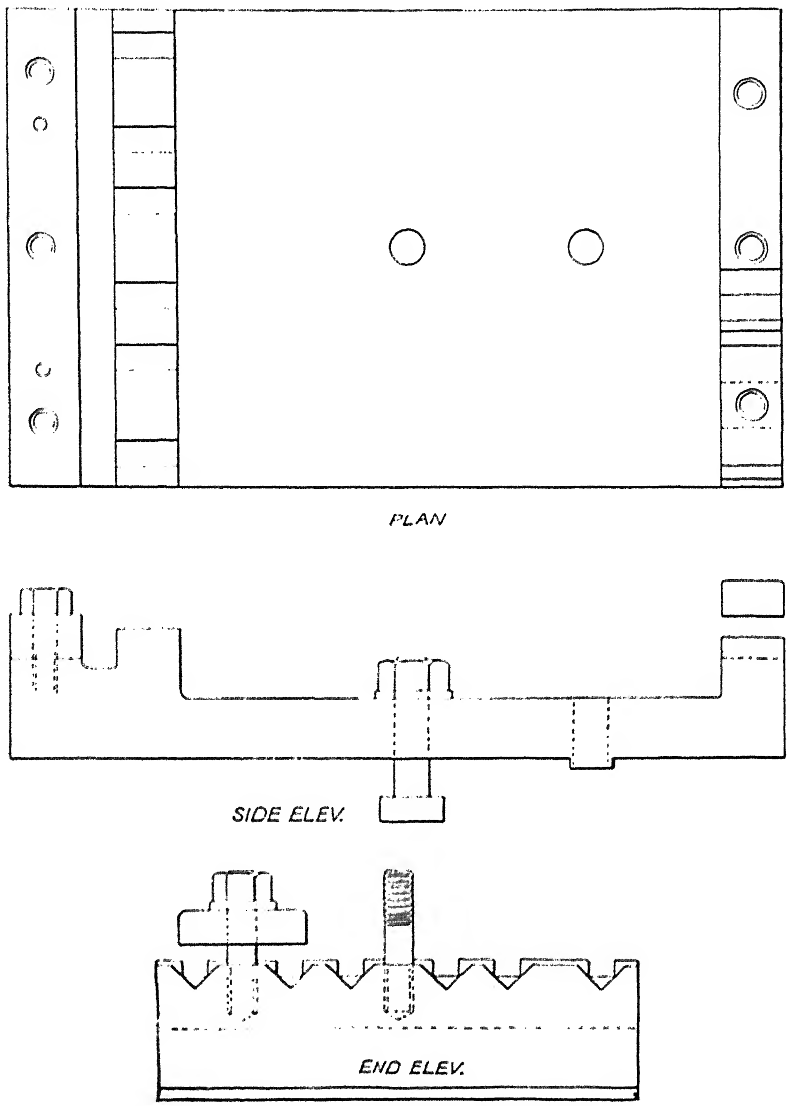


Fig. 41.—Open Fixture for holding Six of the Rods

the fixture, to be thrown back during the removal and insertion of work, or it may be merely lifted off like a cover. Hook bolts or swinging clamp plates secure the two. The fixture may be used for different machines on which

different kinds of operations are performed, or the jig plates may be changed for the operations of drilling or milling. The fixture may be rigid, or it may be made movable so as to present different faces of the work to the

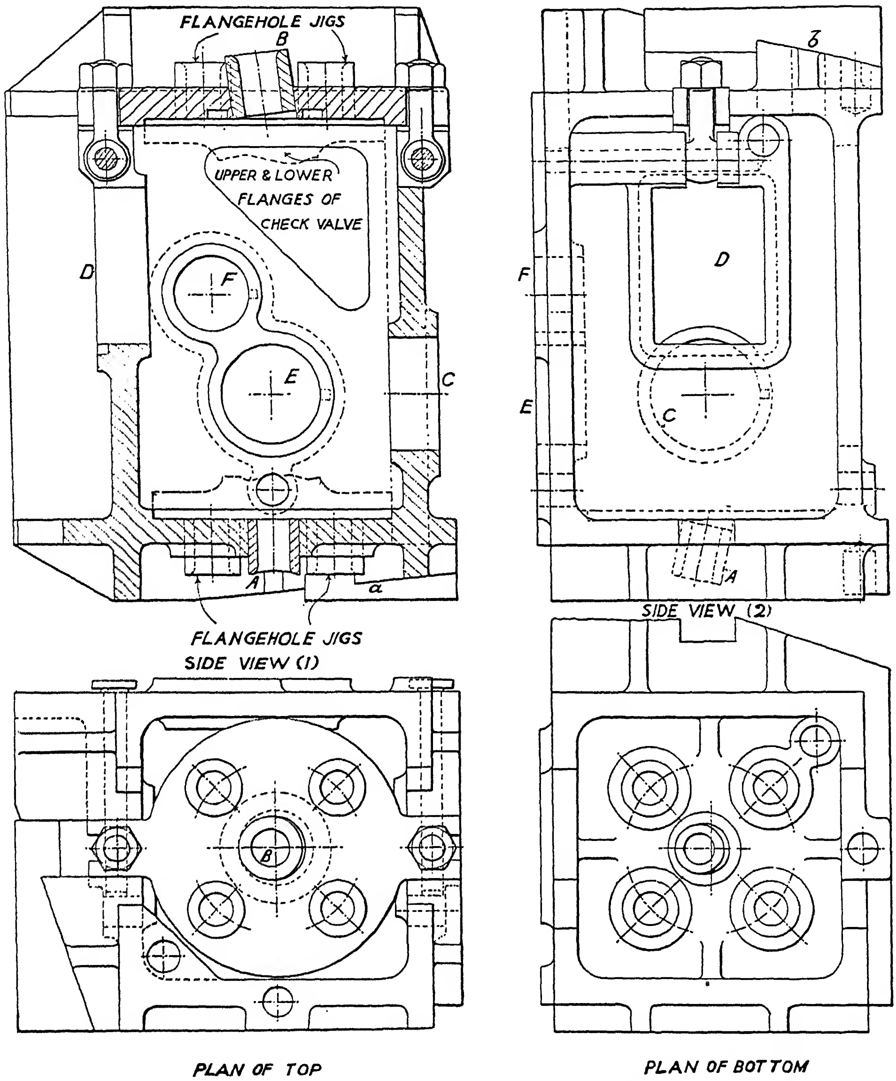


Fig. 42.—Fixture for holding Feed-pump Check Valve

tools. Stop pins and locking devices provide for precise settings on one or on several pieces of work held in tandem.

Example of an Open Fixture.—Fig. 40 illustrates a plunger for a sensitive feed lever, and fig. 41 an open fixture for holding six levers while their ends are being milled to bevels. This is by Messrs. James Archdale & Co., Ltd., Birmingham. The levers rest in vees at one end, in which they

are clamped in pairs, and lie parallel in recesses at the opposite end, where they are brought up against an abutment piece. The ends to be bevelled project beyond the vees, where they are milled with a cutter, divided, in order to permit of readjustment with packing as the edges wear.

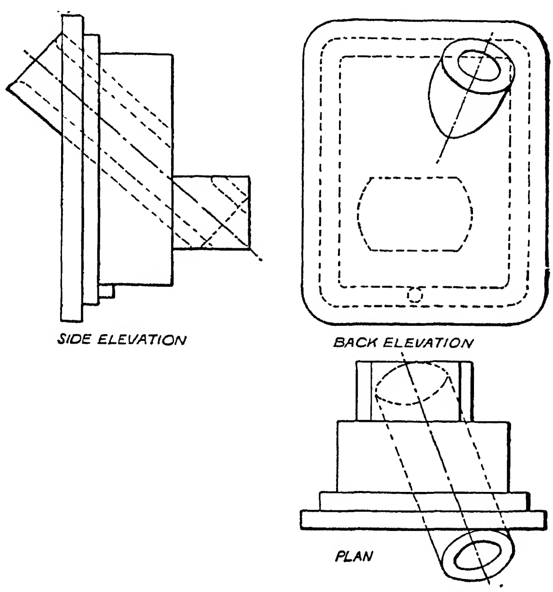


Fig. 43.—Drilling Bush set at Angles in a Locating Block

Example of a Box Jig-fixture.—Figs. 42 and 43 give the principal elements of a fixture by Messrs. Ruston & Hornsby, Ltd., of Lincoln, used in machining the body of a check valve. Its characteristic feature is the provision made for drilling a large number of holes at different angles. The valve, enclosed in the fixture, is located by a flange which enters the shallow recess in the bottom, and is secured by the jig cover. The inside of the cover is recessed to receive a flange on the opposite end of the valve body. The four bushed holes arranged in a circle in the bottom and in the cover guide the drills for the bolt holes in the flanges. Two other holes are drilled at angles through the bushes A and B, to permit of which the fixture has bevelled feet at *a* and *b*. During the vertical drilling, bevelled packing pieces are inserted under these edges. The round hole C receives bushes that interchange for drilling and tapping holes. The oblong recess D receives the locating block, shown detached (fig. 43), that carries a drilling bush at angles in two directions. The fixture is then stood at the required angles on a bevelled support. The holes E and F receive bushes to guide drills for holes in the body.

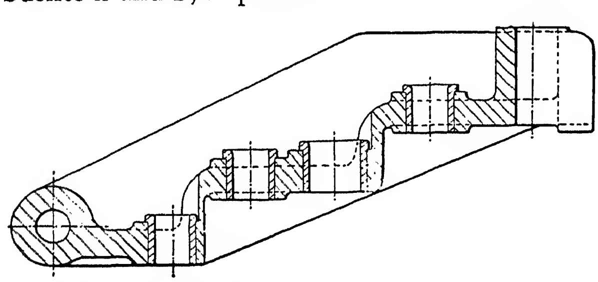


Fig. 44.—Hinged Cover for a Fixture containing Four Drilling Bushes at different Heights

Fig. 44 is the cover of a fixture through which holes are drilled at different heights in the body of a feed pump. It is hinged at the left, and clamped at the right with an eye-bolt in an open slot. Nuts are not run off their bolts, only slackened.

DIVISION V

Measurement and Gauging.—The present system of measurement is precise and positive, and is effected rapidly. The micrometer and vernier tools are used for taking precise measurements, and the fixed gauges check machined dimensions to predetermined limits.

Micrometer Calipers.—In micrometric measurement the pitch of a fine screw thread is subdivided by means of graduations on the periphery of a disk which revolves with it. In the English caliper (fig. 45) the screw usually has 40 threads to the inch, and the "thimble" —the rotating element— has 25 divisions. Since a movement of the screw through one revolution corresponds with a longitudinal movement of $\frac{1}{40}$ in., one partial turn of the thimble through one division moves the screw through $\frac{1}{25}$ of $\frac{1}{40}$ in. $= \frac{1}{1000}$ in. To enable the exact longitudinal movement of the screw to be read, the barrel or "sleeve"—the cylindrical body—is divided in a line parallel with the axis of the screw into 40 parts, but only every fourth division is stamped 1, 2, 3, &c., from zero, corresponding with 0·1 in., 0·2 in., 0·3 in., &c. Each of these subdivisions thus represents 25 thousandths of an inch. To read the caliper, therefore, multiply the number of divisions visible on the scale on the barrel by 25, and add the number of divisions on the scale of the thimble reckoning from zero.

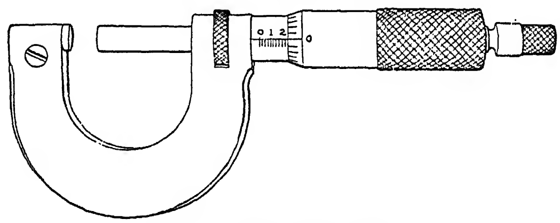


Fig. 45.—Micrometer Caliper

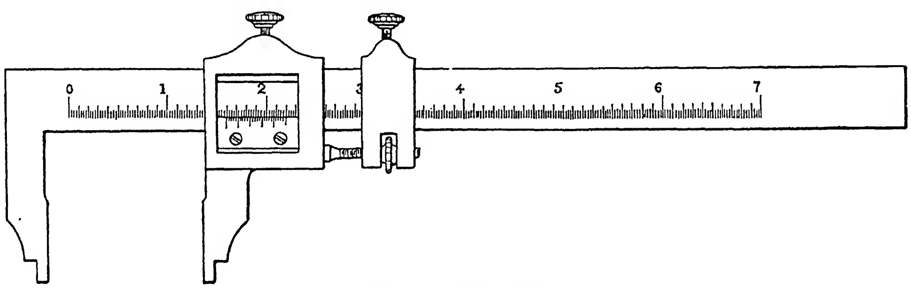


Fig. 46.—Vernier Caliper

Vernier Calipers.—A vernier is fitted to instruments made for making the finest measurements. An inch is usually divided (fig. 46) into tenths, and a vernier, of length equal to nine of the divisions, is divided again into ten parts. Each subdivision on the vernier is therefore $\frac{1}{100}$ in. shorter than one division on the rule. When thousandths have to be read, each tenth division on the rule is subdivided into four, giving forty to the inch. Twenty-four of these parts are taken on the vernier and subdivided into twenty-five

parts. Each subdivision on the vernier is thus shorter than those on the rule by $\frac{1}{1000}$ in. Hence the rule: Note how many inches, tenths, and parts of tenths the zero point on the vernier has been moved from the zero on the rule. Count upon the vernier the number of divisions, until one is found which coincides with one on the rule. This division will correspond to the number of thousandths to be added to the distance read off on the rule.

Fixed Gauges.—Some fits in mechanisms must be tight and others easy. Differences made in dimensions for the various kinds of fits are termed "allowances". The very minute variations that are permissible are called "tolerances". The term "limits" includes allowances and tolerances, and gives the name to the "limit" gauges, which are generally guaranteed to be correct within 0·0001 in. Usually the hole is taken as the basis for measurement, and the allowance is made on the shaft, but this is not invariable.

For many years after the introduction of gauges, the Whitworth cylindrical forms only were used—the "plug" and the "ring". No attempt was made at first to include limits. The plugs fitted their rings exactly on the application of the merest film of oil with the finger. Tight and easy fits were made by the exercise of judgment. These have largely given place, except for tapers, to the flat "snap" gauges, partly because these show a dimension more finely than the others, and also because they can be used on pieces that are not cylindrical. In some forms there is a gauge, fixed by two opposing jaws, at one end of the instrument that should pass over the work, and at the other a pair of jaws that must not. They are called "go" and "not-go" gauges. In large gauges the instruments are separate or combined.

The Johansson System.—In this system, end measuring blocks of rectangular shapes are employed. A set comprises eighty-one blocks divided into four series. The first ranges from 0·1001 to 0·1009 in. by increments of 0·0001 in., the second from 0·101 to 0·149 in. by 0·001 in., the third from 0·050 to 0·950 in. by 0·05 in., the fourth measure 1 in., 2 in., 3 in., and 4 in. The blocks in the first series will divide up the spaces between those of the second series, and series three and four can be divided by the first and second series. By means of combinations of the eighty-one gauges, 80,000 different sizes can be obtained. These combinations are of much value in providing a ready method of checking the accuracy of a number of fractional dimensions. They are used both for checking work directly, and for testing other measuring instruments, as calipers, limit gauges, measuring rods, jig parts, &c. Various holders are provided. The most remarkable feature of these gauges is that the blocks adhere to each other by reason of the fine accuracy of their surfaces.

CHAPTER IV

The Work of the Machines

DIVISION I

The Lathes.—These include some forty to fifty groups, each having well-defined spheres of operation. They range in size from very small to mammoth dimensions, while extreme machines have little in common except the fact that the work revolves between centres or in chucks. The prototype of most of these is the standard, "self-acting, sliding, surfacing, and screw-cutting lathe"—the all-round machine-tool, the economic value of which gets less and less as specialized manufacture increases.

Short screws, and those of which large quantities are required, are now manufactured on turret lathes, screwing machines, and brass-finishers' lathes. The longer screws and stays are still made in screw-cutting lathes.

The later lathes, fig. 47 being an example, nearly all differ from the earlier in the provisions made for speed and feed changes. Stepped belt cones are now almost entirely superseded by all-geared heads. When cones are retained, with back gears, speeds are arranged in carefully chosen ratios instead of in a haphazard way. All-geared heads, being driven from a single

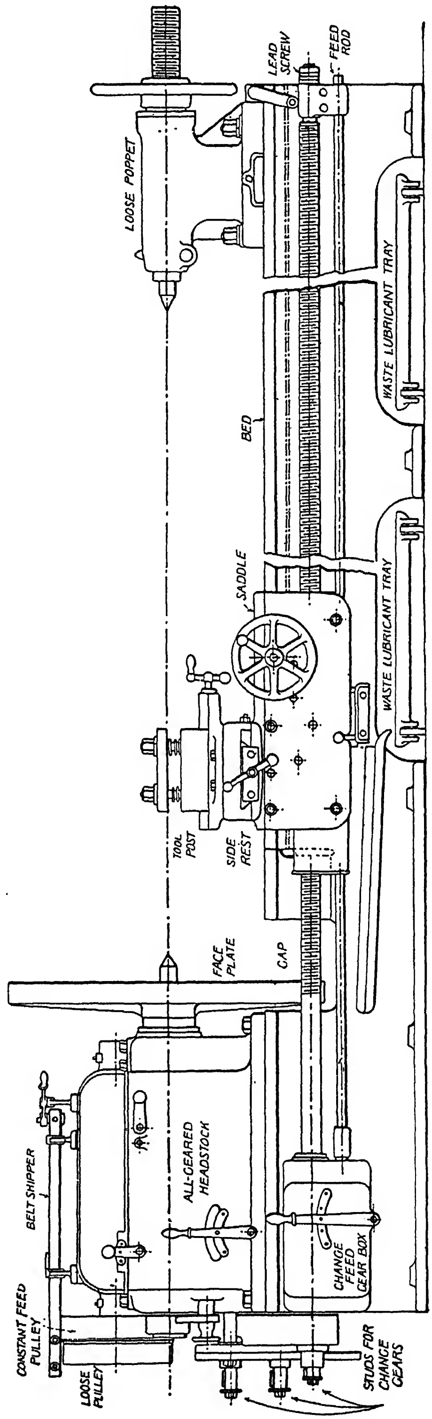


Fig. 47.—All-geared Head, Self-acting, Sliding, Surfacing, and Screw-cutting Lathe. Pulley speed, 650 r.p.m. Twelve spindle speeds, 4·5 to 170 r.p.m.

pulley running at a constant speed, can be driven equally well by a belt drive from a countershaft or by a motor. Feeds are seldom taken now from a "back-shaft", but from a "feed-shaft" in front of the lathe.

Another innovation the hollow spindle allows stock bars to be passed through from the rear of the headstock to be gripped in a chuck at the front. It has caused many changes, in the design of spindle journals and bearings, which are of value.

In all the common lathes a single tool is mostly used. This is so severe a handicap on production that a large number of lathes have been built for multiple-tool cutting. Some of these are automatic in operation. The distinguishing feature of these is the mounting of a battery of tools in the holder of the slide rest to cut simultaneously or in rapid succession. These arrangements are used chiefly in the manufacture of articles in which several different diameters occur, with shoulders and faces.

DIVISION II

Turret Lathes and Screw Machines. The difference between a turret and a capstan lathe is that in the former the tool holder is mounted on a saddle that slides along the bed; in the latter, the tool holder slides along a saddle that is fixed to the bed. The practical result is that the range of movement of the turret is more extensive than that of the capstan. The first is also made in larger dimensions than the second. The difference between a screw machine and a capstan lathe is that the first is fully automatic in action hence often termed an "automatic" while the latter is not. The movements of the first are caused by cams mounted on drums and on disks. The movements of the second are produced generally by gears, feed rods, &c. The screw machine may or may not be equipped with a turret. The work-holding spindle is most commonly single, but many lathes now have four, five, or six spindles, each carrying its piece of work which is brought round in turn to the tools.

Although many common lathes are fitted with turrets, the "turret lathe" is a distinct type. It has a hollow spindle for bar work, and in many cases has a chuck for face work, though the tendency now is to allot these functions to distinct lathes. It has a cross-slide, with a tool post at front and at rear. A chasing saddle is frequently included for cutting screws of greater length than can be done conveniently from the turret. The hexagonal turret, with tools mounted on each face, and with its rotational movements synchronized with those of the work, far outdistances the common lathe in speed of production. It is usual to scheme the operations in such a way that a complete cycle turning, drilling, reaming, with rough and finishing cuts, tapping, &c. — can be finished on a single piece during one rotation. In the simpler articles more than one piece can be tooled during one rotation.

Stops.—A feature common to all turret lathes is the fitting of stops to determine the lengths and diameters of the work being machined. This avoids tentative measurements. Originally a single fixed stop was used. This is

still retained in some instances, and is fixed at the rear of the turret. The one stop serves for every tool, so that each tool has to be adjusted by it. This is abandoned in the better class of lathe in favour of a separate stop adjusted to each tool. For a six-sided turret, six stops are fitted. For turrets that have cross-traverse movements, similar stops are included to determine diameters. The cross-slide again has its stops for the front and back tool posts. Another kind of stop is included in the setting of the turret tool itself. One determines the precise longitudinal position of the bar thrust through the hollow spindle. Others, in box tools, set the

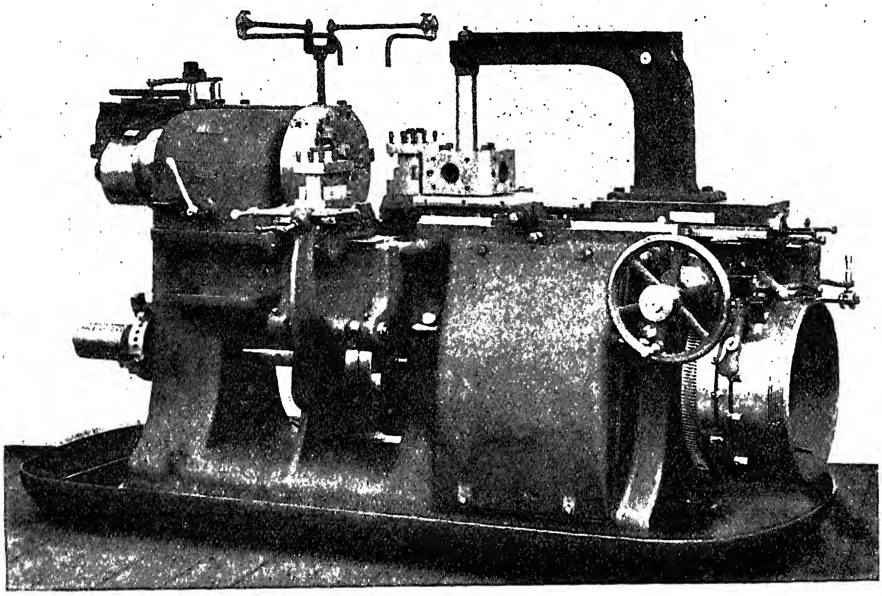


Fig. 48.—Automatic Turning Machine

length of a cut, or the throw-out of an opening die, while vee and roller steadies fix diameters. In the screw machines the setting of the cams determines the lengths and the diameters of cuts.

Automatic Turning Machines.—It is a remarkable fact, illustrative of the present trend of machine-shop practice, that just as the turret lathes and automatics have taken much work away from the common lathes, so the turret lathes and automatics in turn are being hardly hit by other machines possessing simpler and more restricted functions. This is largely due to the fact that economical production requires the dividing of certain classes of work between distinct machines. Generally heavier cutting can be done and a larger number of tools brought into action. As a result, many lathes are now fitted with very substantial rests for holding multiple tools. One group, represented by several designs, is the automatic turning lathe (fig. 48). The functions of this group are restricted, but it out-distances the turret

lathe group in some classes of work, owing to the simplicity of its functions, the ease of setting-up, and its substantial build.

Illustrations of Turret Work.—Some examples of this kind, done on lathes by Messrs. Alfred Herbert, Ltd., are given in succeeding figures.

Fig. 49 shows the distribution case of a rotary aero-engine being produced on a combination turret lathe. The tool seen in operation is a counterbore, the one swung round towards the front is a trepanning tool, which cuts a recess of 10-in. bore, $1\frac{7}{16}$ in. wide by 4 in. deep. These two tools are used

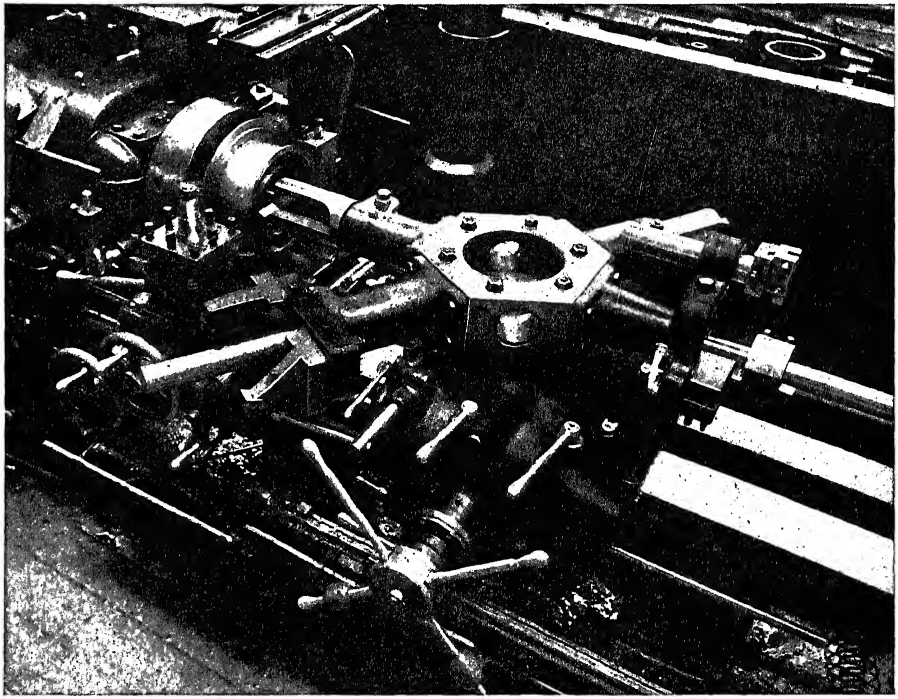


Fig. 49.—Distribution Case of a Rotary Aero-engine being turned on a Combination Turret Lathe

with feeds as coarse as 88 cuts per inch, and between them they remove over 100 lb. of metal.

Fig. 50 illustrates the second operation on a propeller boss for an aero-engine. The work is held on a face plate form of fixture, and located from the tapered bore with a spring tapered peg. The boss is turned with an allowance for grinding, faced and counterbored, and the hole threaded with a collapsing tap.

Fig. 51 shows the rough-turning of the fins of an air-cooled aero cylinder, one of which is seen on the turret. The work is being done with a gang of tools similar to parting-tools mounted in a special tool holder at the back of the cross slide, all operating simultaneously. The piece is chucked with an expanding arbor, and steadied with a revolving support carried in the turret.

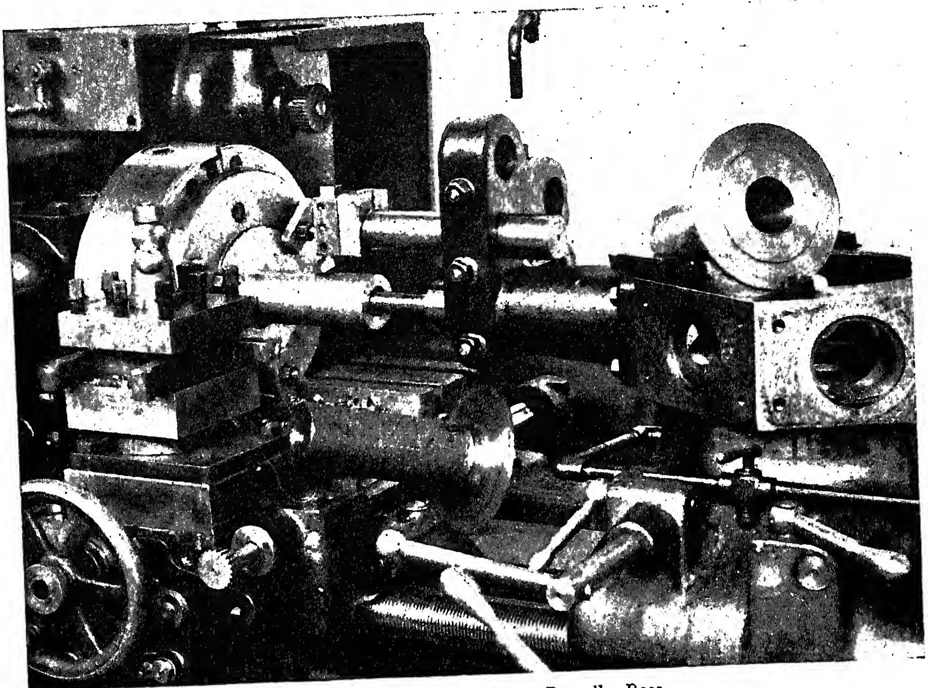


Fig. 50.—Second Operation on Propeller Boss

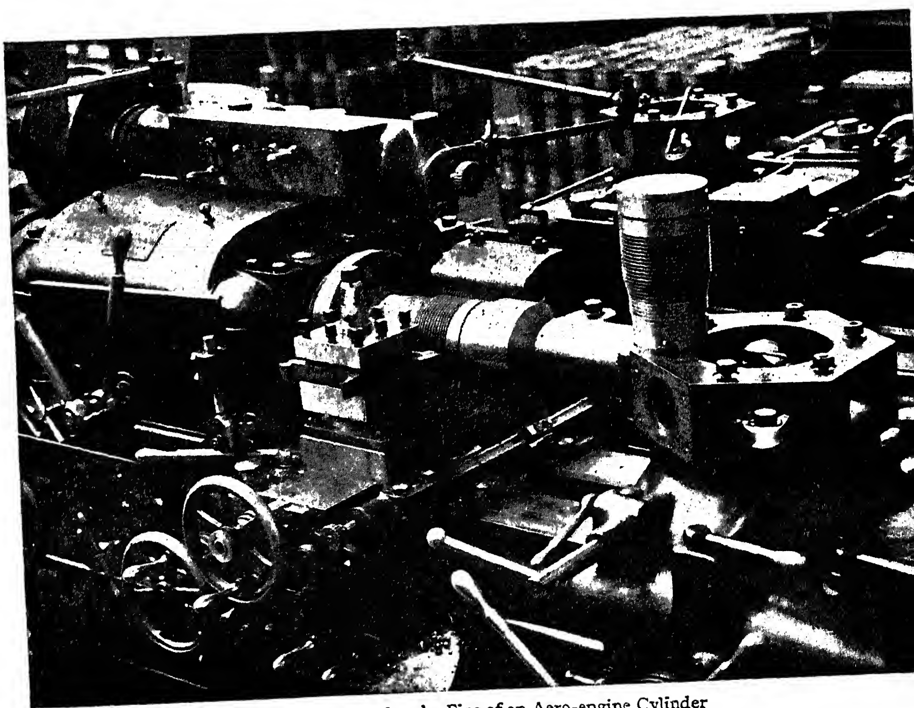


Fig. 51.—Forming the Fins of an Aero-engine Cylinder

DIVISION III

Drilling Machines.—The practice of drilling commonly includes operations allied to drilling, such as reaming, tapping, facing, arboring, bossing; and the machines range from the sensitive high-speed group to

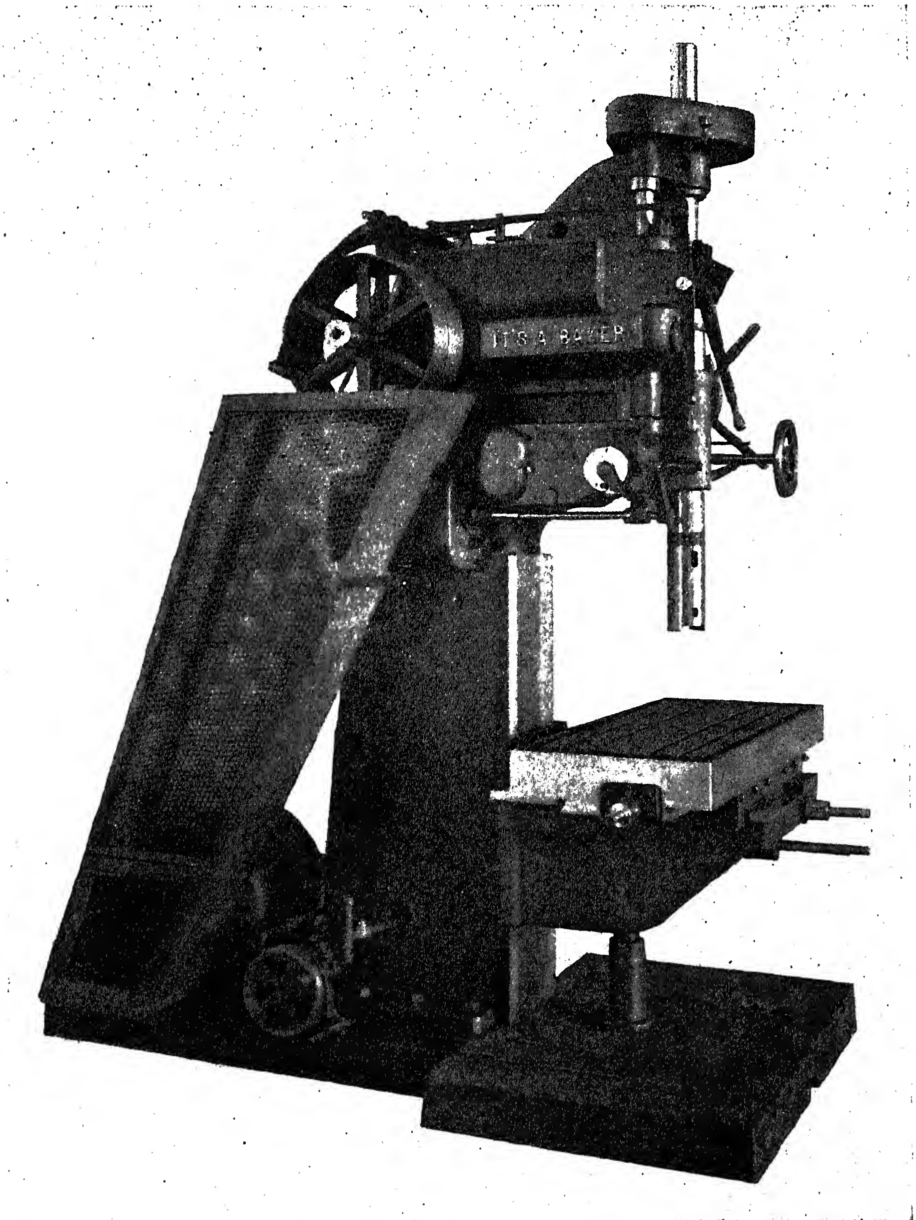


Fig. 52.—Heavy Drilling Machine

the heavy multi-spindle designs, and embrace those special machines that are built to deal with a single product exclusively. Though each group retains its characteristic outlines, all the hidden details have been greatly modified. Changes of equal moment have been made in the treatment of the work done, and its mode of presentation to the machines, with which the

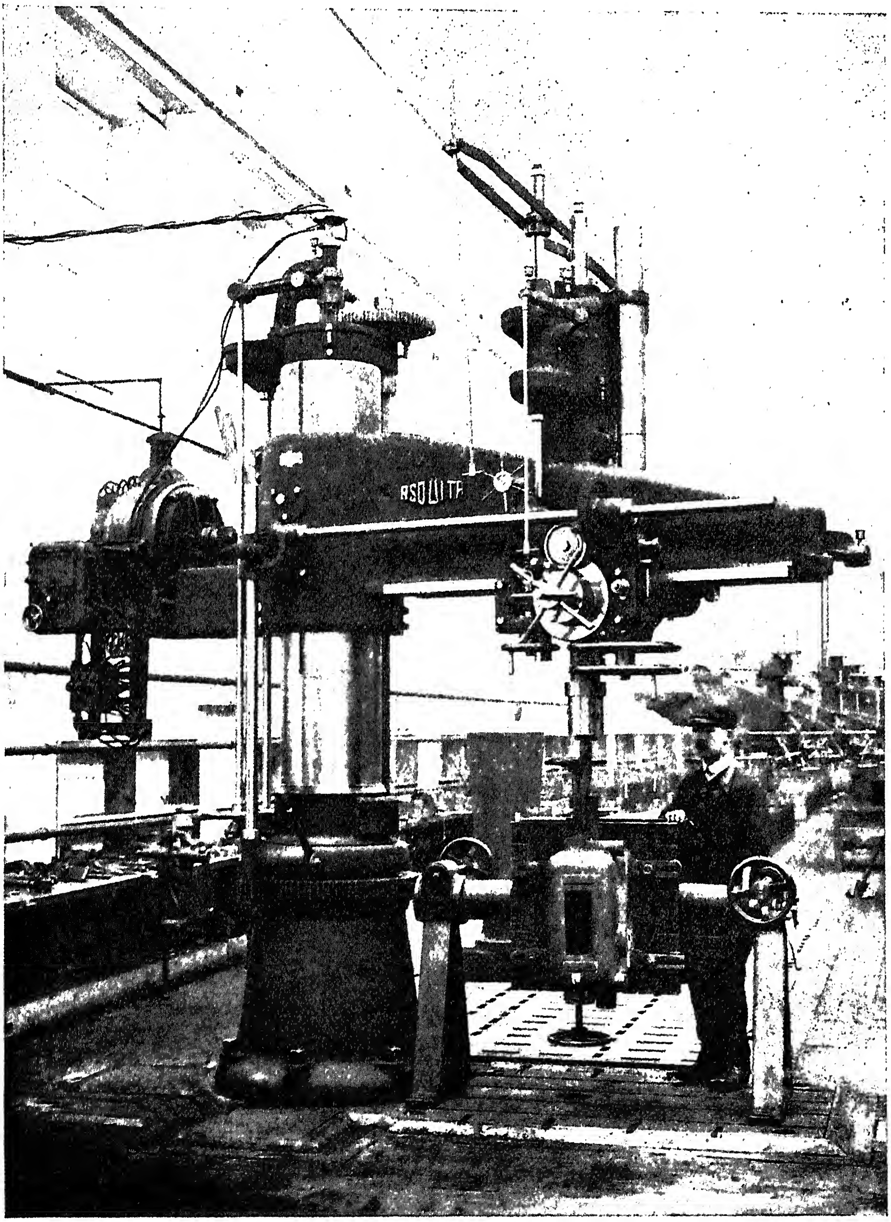


Fig. 53.—Radial Drilling Machine, Electrically Driven, Central Thrust, with Universal Tilting Work-table

problem of attendance is linked. The practice of drilling single holes from a single-spindle machine is adopted less frequently than it used to be, and, instead, the practice of multiple drilling is resorted to where possible. In the

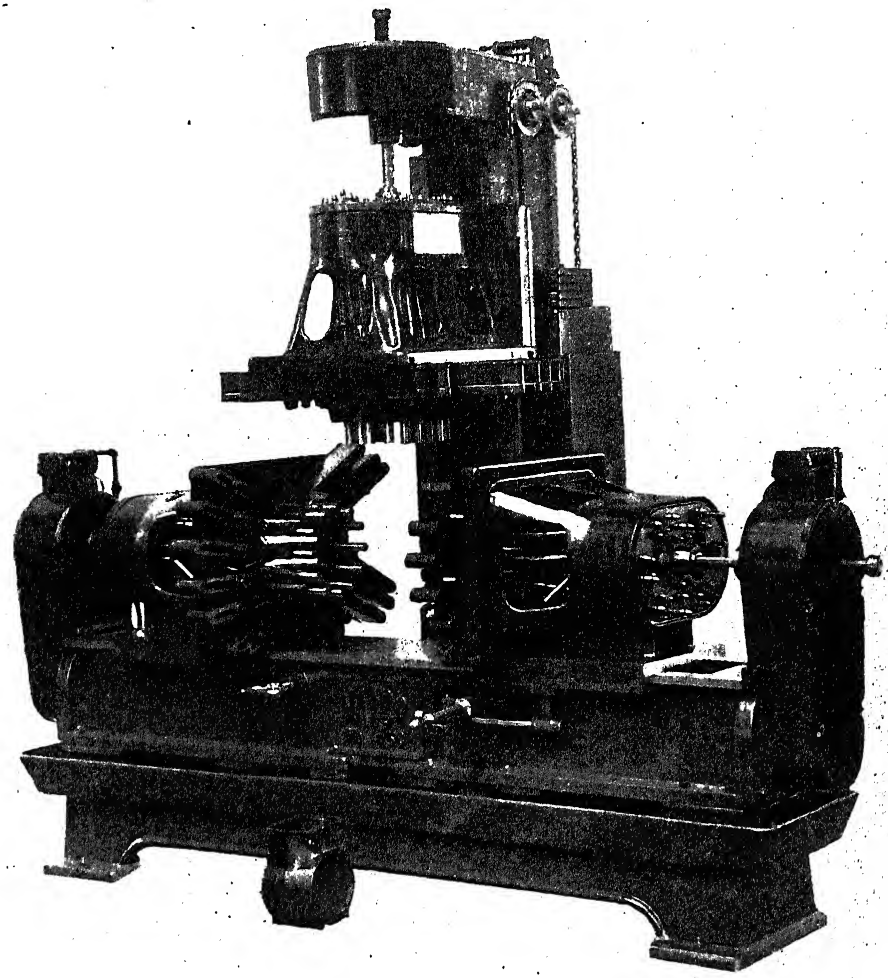


Fig. 54.—Three-way Horizontal Multi-spindle Machine

majority of cases, jigs or fixtures, or both in combination, are now employed in drilling and reaming operations.

Selected Machines.—Fig. 52 illustrates a stiff drilling machine by Baker Bros., Toledo, for boring motor cylinders. One motor firm has 350 "Baker" machines in its plant, many being arranged in gangs. The machine shown is electrically driven, being started, stopped, and reversed with a push button. In all the series the speed ranges are eight in number, and feed ranges twelve, the numbers being suited to the sizes of machines.

Capacities range from $\frac{1}{2}$ to $4\frac{1}{2}$ in. diameter in steel, and from 4 to 6 in. diameter in cast iron. A 1-in drill can be fed in steel at the rate of $14\frac{1}{2}$ in. per minute, a 1-in. drill in cast iron at the rate of 24 in. per minute.

Fig. 53 shows one of the Asquith radial machines, electrically driven, having a central thrust to the spindle. The firm's universal tilting table is a valuable adjunct, since it enables each side of a piece of work (except that in contact with the table) to be machined at a single setting. The table pivots through a complete circle on trunnions, and carries two independent tables on opposite faces, each of which can be given a rotary movement by hand. These tables have tee-grooves for the attachment of work. Drilling, reaming, and facing can be done at different angles.

At present, opinion is divided concerning the best uses to which single-spindle machines disposed in gangs, or multi-spindle machines, may be put. The spindles are disposed in gangs, or in clusters. Fig. 54 shows a highly specialized design to deal with work to be machined from three faces, without resetting it. The machine shown is by the National Automatic Tool Company of Richmond, Indiana. Many of the multi-spindle tools have been evolved for motor work, for drilling crank cases, cylinders, gear cases, cylinder heads, connecting rods, &c. They produce a large number of holes simultaneously instead of singly. They also ream, counterbore, and face the holes.

DIVISION IV

Boring Machines.—The difference between a machine that drills and one that bores is that the latter deals with larger holes, which fact influences the design and the operating mechanism. Though in very many machines boring is included with drilling, only holes of small diameters and of moderate lengths can be bored in these machines. Since these machines are for general purposes, tapping, facing, and often milling are included. Here a large range of speeds and feeds is essential. A modern machine of this class will have as many as eighteen spindle speeds, ranging from 7 or 8 r.p.m. to 200 or 250 r.p.m., and say nine feeds, which, given in inches per revolution of the spindle, range from 0·006 in. or 0·007 in. to 0·115 in. per revolution. If tapping and milling are not included the range need not be so extensive.

An excellent example of a horizontal-spindle design is the "Pearn-Richards" combined machine, the functions of which include drilling, boring, tapping, surfacing, milling, and, with a suitable attachment, screw-cutting. Thirty-two variations in speed are provided, and eight rates of feed, applicable to the longitudinal, transverse, and vertical slide movements. The illustrations are nearly self-explanatory. The machine is manufactured by Messrs. Frank Pearn & Co., Ltd., Manchester.

Fig. 55 shows one of the Crossley gas-engine beds being bored and faced with tandem cutters in the bar. The bar is driven from the head and supported in the hinged bearing on the stay at the right hand. The square table

on which the bed is carried can be rotated on a pin to present different faces to the work. It is also detachable. Fig. 56 shows the same bed turned round 90° to have the cylinder end faced and bored to receive the liner. After this, an edge-mill machines the water inlet and outlet and cam shaft faces.

Vertical-spindle Machines.—These are the most popular types at present for dealing with motor cylinders and those of the smaller gas engines. The spindles are massive to enable them to withstand heavy cuts in bores

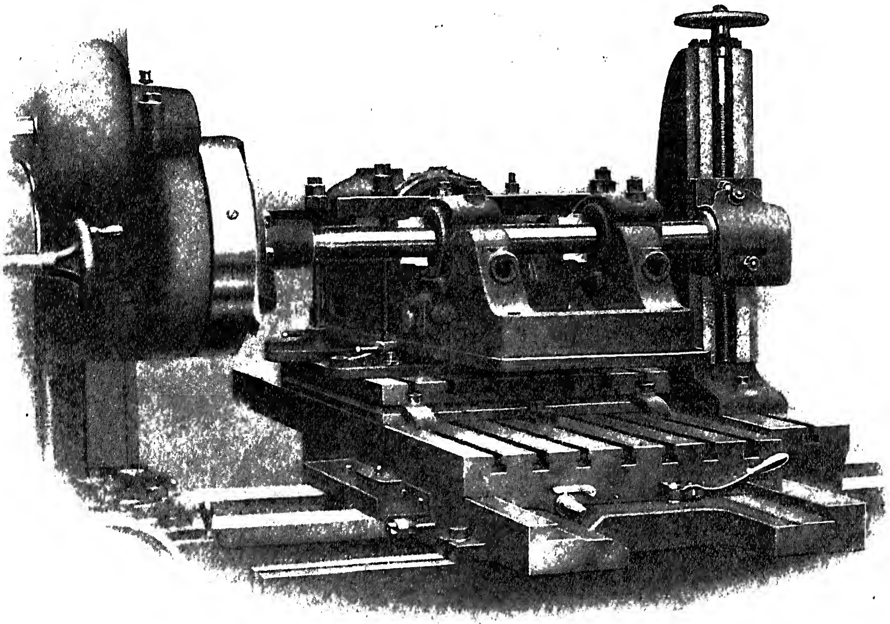


Fig. 55.—Boring and Facing Crank-shaft Bearings of Gas-engine Bed (Pearn-Richards Horizontal Combined Machine)

that range, say, from 4 to 6 in., and in lengths up to about 16 in. The analogue of this class of spindle is that of the horizontal snout boring machine, introduced originally to deal with cylinders of small bores and having either one or two spindles. This is being supplanted by the vertical design, to which multi-spindles are more readily fitted, while the workman has a better view of the operations, and the cuttings fall clear away at once instead of choking the action of the tools. It is also easier to design and handle fixtures for the vertical spindle machines than for the others.

With the rapid extension of automobile work the vertical-spindle machines have been subject to many changes and improvements. Single-spindle machines are ranged in gangs, three or four comprising a working unit. The cylinder, held in a suitable fixture, is rough-bored under one spindle,

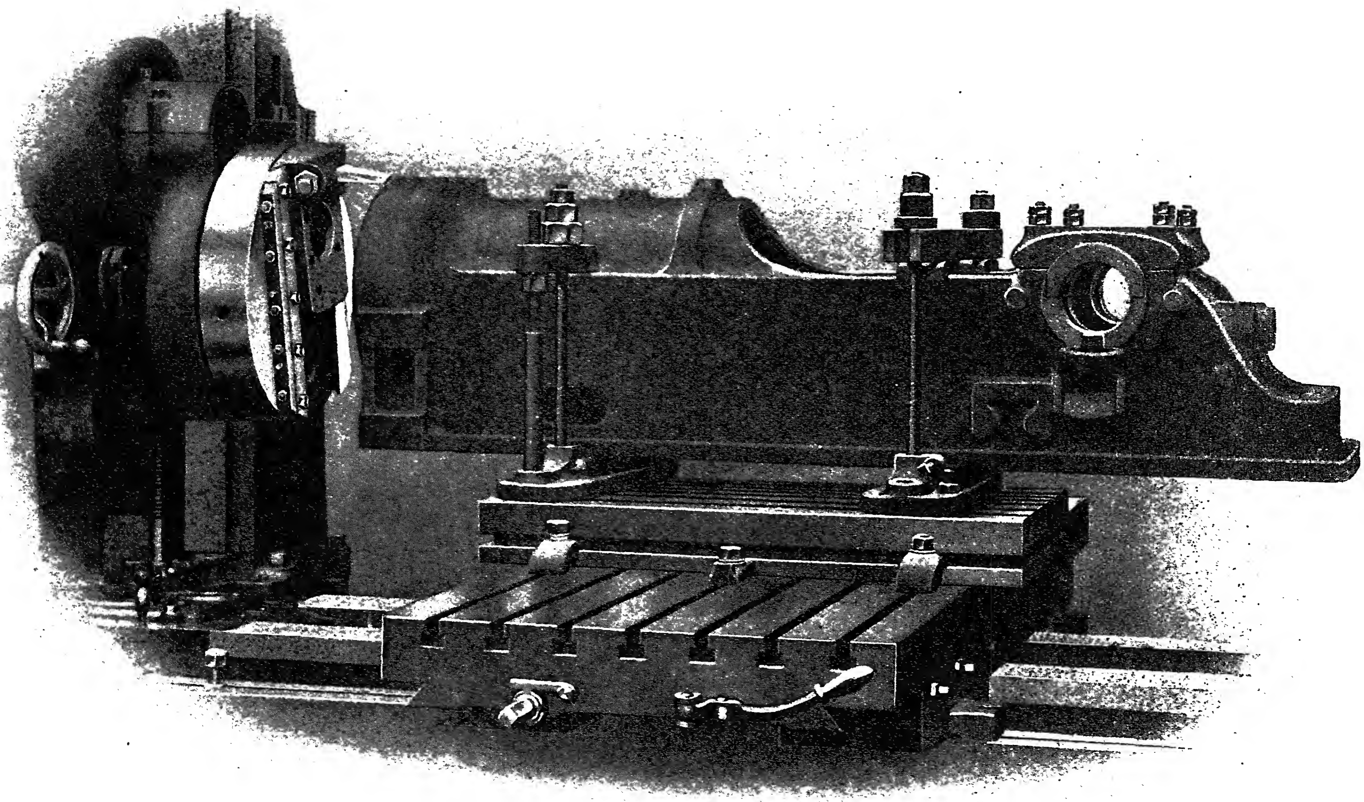
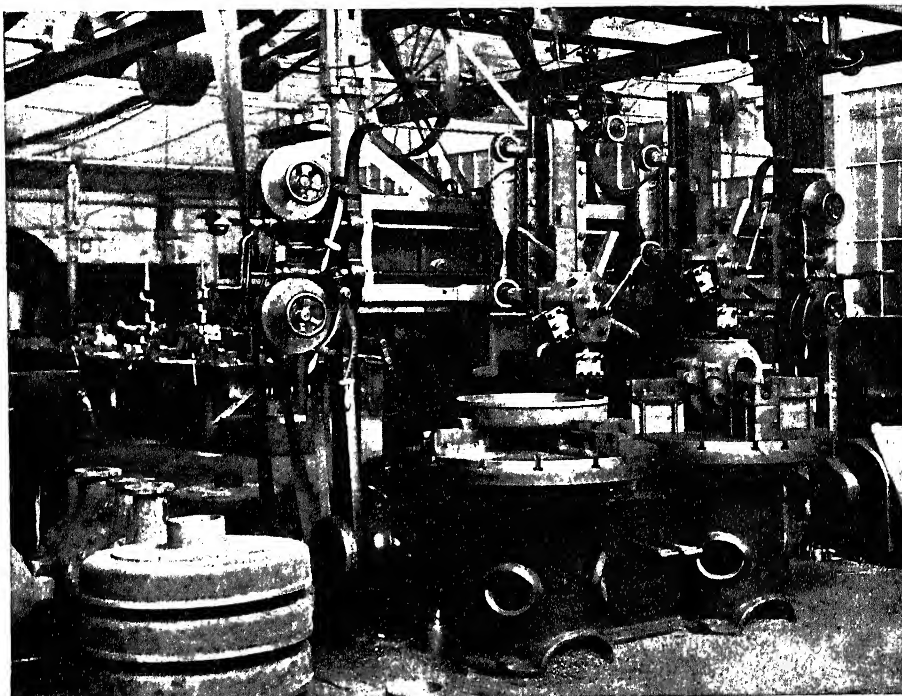


Fig. 56.—Facing Cylinder End of Gas-engine Bed. Followed by boring and milling seatings

(p. 220)

finish-bored on the next, and reamed in a third, with possibly a finish reaming to follow. The fixture retains the casting accurately, and a jig locates and coerces the boring bar.

When a casting includes more than one cylinder bore the same system is adopted. But here the single-spindle machine is at a disadvantage. Twin and multi-cylinders, therefore, cast *en bloc*, are better dealt with in machines having as many spindles as there are bores, all operating simultaneously. The boring or reaming of two, four, or six cylinders occupies no more time



(p. 223)

Fig. 57.—Two Distinct Pieces of Work being tooled on one Machine

than that of one. Then, to avoid loss of time in changing of tools and altering speeds and feeds, work if held in a fixture can be transferred between adjacent machines for rough- and finish-boring and reaming.

Boring and Turning Mills.—These are strictly lathes in which the axis of revolution of the work is vertical. They afford conveniences relating chiefly to the chucking of work on a horizontal face plate and to the very large diameters that can be dealt with thus. The advantages are most apparent when a number of separate pieces have to be set up, and when a piece of work requires loose packing, bolts, and clamps instead of being gripped in chuck jaws. And, when articles are not concentric, counter-balancing necessary in the common lathe is not required in the vertical machine. Another point in the vertical machines is that the work tables are well supported, and provision is frequently included when doing light

turning for running them on the spindle only, and for massive work to support them on an annular ring nearly as large as the diameter of the table. Very many machines have two work-holding tables. At the opposite extreme, machines of large dimensions will take pieces from 30 to 40 ft. in diameter. On all, a cross-slide, much like that of a planer, receives the saddles that carry the tool slides. Frequently a turret is mounted on a slide, carrying a battery of tools. Boring and turning are performed simultaneously, and turning may be done from two tool-holders on opposite sides of a diameter. A photograph of work being done on the machines by Messrs. Webster & Bennet, Ltd., of Coventry, will serve to indicate the utilities of the boring and turning mills equipped with turrets. In fig. 57 two distinct castings are being tooled on one machine, bored, turned, and faced, in charge of one attendant. Loose chuck jaws hold the work in each case.

DIVISION V

Milling Machines.—These are all derived from the Lincoln millers, to which they bear no resemblance beyond the fact that they all employ rotating cutting-tools with many teeth.

The Lincoln Machine.—This is used for plain horizontal and face

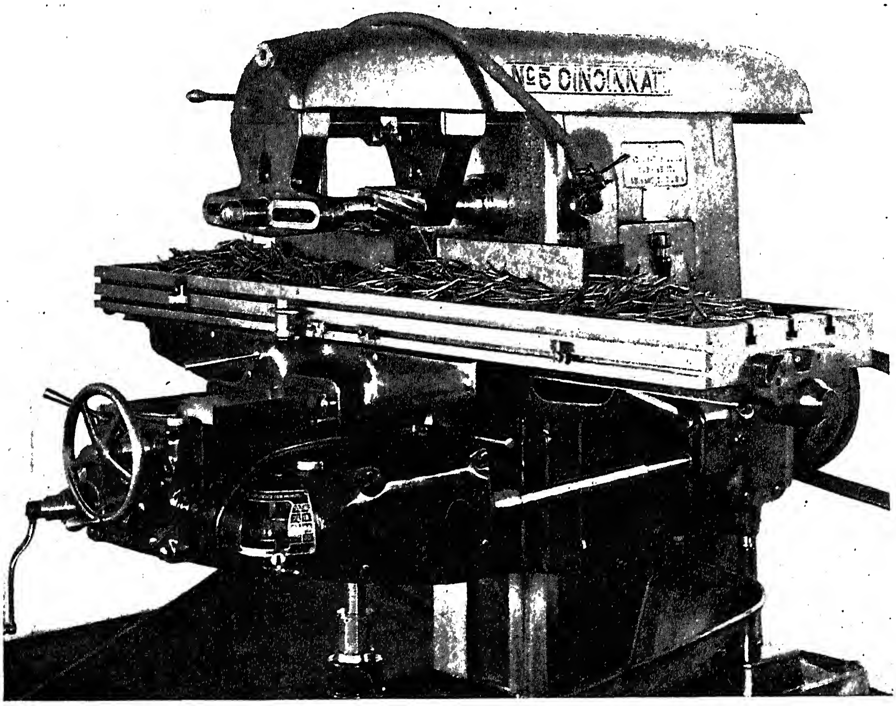


Fig. 58.—Slab Milling on a Plain High-power Cincinnati Machine. Material Steel, width of cut 5 in., depth ½ in., feed 19 in. per minute. Material removed 24 c. in. per minute.

milling. Generally the bed is of the lathe type, and receives the saddle on which the work-holding table has a cross-traverse movement. In some cases the bed resembles that of a planing machine, along which the work table traverses, this giving a longer range of feed than the other. As the table cannot be elevated, vertical movements are imparted to the spindle, which slides in its bearings in or on the faces of housings fixed at the left-hand end

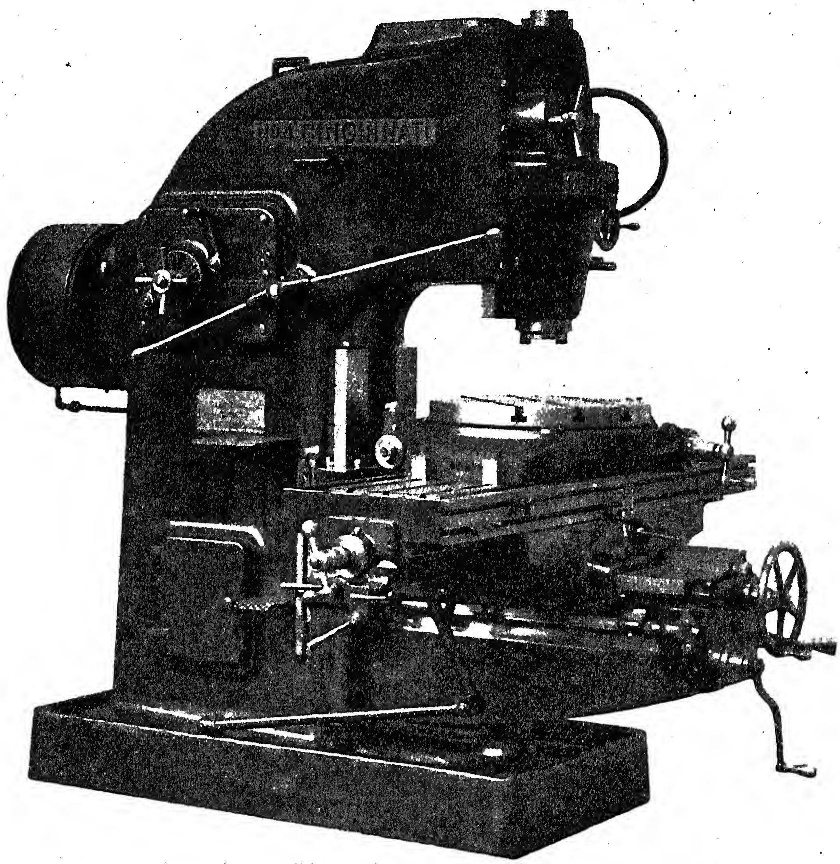


Fig. 59.—Vertical-spindle Machine

of the bed. An arbor support is provided in a tail block at the right hand, adjustable along the bed.

The Pillar and Knee Machine.—Also frequently termed a horizontal spindle machine, this has a hollow column that carries a headstock on top, and a knee on one face, which receives the work table and its slides. All vertical adjustments are imparted to the knee. Machines are plain or universal, the first being restricted to rectangular movements only, that of the table along its saddle, that of the table alone, longitudinally, and that of the knee vertically. The second includes in addition a spiral head, an index

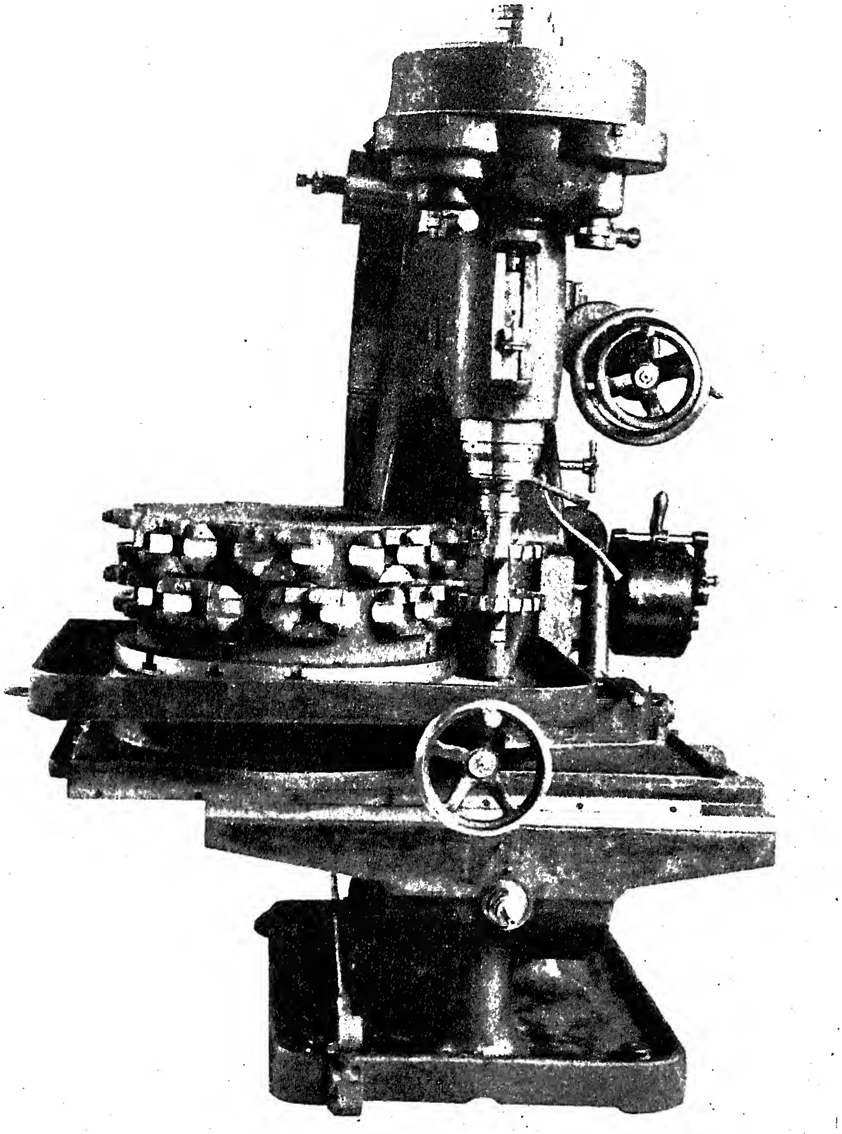


Fig. 60.—Milling the Inside Faces of Universal Yokes with two Inserted Tooth Cutters (p. 226)

plate, a sector, change gears, and a swivel table. By these additions a rotary movement can be given to the work while the table is being fed at any angle. Any gear-cutting, specially that of spirals, and the teeth of cutters, can be produced thus. These machines are marked by increased strength and stiffness of late years, and speeds and feeds are very commonly being imparted through boxes of gears. In Fig. 58 will be found an illustration of a

powerful Cincinnati " manufacturing " machine. The rigidity afforded by the overhanging arm alone steadies the cutter sufficiently without using the front brace.

Vertical-spindle Machines.—These (fig. 59) in their broad outlines suggest the common drilling machines. They have a column, arched above to carry the vertical spindle, which receives edge or face cutters in its nose, and is frequently belt-driven. A knee adjustable vertically carries the work table and slides. Numerous variations occur in the details of these machines, one of the most valuable being that of adaptation to profiling.

Plano-millers or Slabbing Machines.—These were the latest to be developed, but they are being employed increasingly. They are built on the planer model, with a long bed and work table, flanked by vertical housings, carrying an adjustable cross-rail, with spindle heads. They often successfully rival the planers, since a single cut is taken over a wide face during the table travel, instead of requiring a large number of reciprocating movements. Their utilities are enhanced by the fitting of horizontal spindles on one or both sides in addition to those on the cross-slide, sometimes also provided with angular settings, while some machines have circular tables on the one that reciprocates. The sphere of these machines lies chiefly in massive work, much of which is arranged in tandem, frequently with the help of fixtures. Edge and face milling are both done, and a large proportion of gang milling.

Continuous Milling.—This, the last development in this kind of machining, includes that done on plano-millers, but it is generally understood to refer to that performed on the rotary tables of vertical-spindle machines, and is nearly invariably associated with the employment of fixtures. Fig. 60 illustrates a Becker machine machining the inside faces of yoke pieces, employing two 7-in. inserted tooth cutters. Thirty-six pieces are held in the fixture, and the production is 160 pieces per hour. Connecting-rod ends are milled on their faces, with pairs of inserted tooth cutters, on a double-spindle machine. They are set diagonally in place in the fixture to lessen the space left for " cutting wind ".

DIVISION VI

Reciprocating Machine-tools.—These include the following tools: (1) The standard planing machine with bed, work-holding table, housings, and cross-rail, and tool-boxes; the derived machines are: the open-side planers, pit planers, well planers, portable machines, and key grooving and broaching machines. (2) The shaping machines having single or double rams, and tool-heads. The portable shapers are a small group. Gear-tooth planers are shaping machines of short stroke. (3) The slotting machines, in which the tools reciprocate vertically, one or two tools being carried in the ram. The tables are simple, with rectilinear movements, or compound, to include a circular motion for circular slotting.

Widely though these machines differ, they are properly grouped as

reciprocating because the cutting only occurs on one stroke. The return stroke simply brings the work or the tool back to its original starting-point in readiness for another trip.

The common planer is a machine for general purposes. It takes any work within its capacity. The functions of the shaper and the slotter are extremely limited, since they only deal with small surfaces. The portable machines are employed to perform their functions on massive articles in situ or on floor plates on work that cannot be set on machines. The key-grooving and the broaching machines are specialized designs that cut narrow

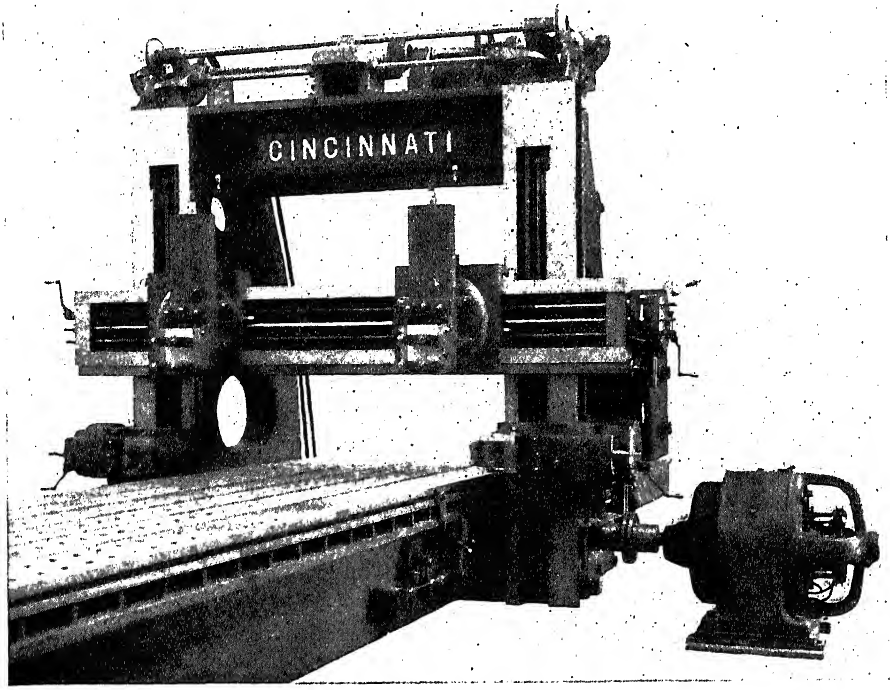


Fig. 61.—Motor-driven Planer

slots in bores and elsewhere. In some of their functions they resemble the slotting machines, but they deal with lengths impossible on the slotter, and produce sections at one stroke that could only be done much more slowly on this machine.

The principal improvements in the later planers have been the following: (1) An increase in cutting speeds, and provision for effecting several changes in rates suitable for different metals and alloys. (2) A rapid rate of return. (3) The cushioning of the reversal with springs to absorb and give out power on the return stroke. (4) The employment of a light aluminium alloy for the driving pulleys to lessen the inertia at reverse. (5) Driving at high speeds with narrow belts, using separate fast and loose pulleys for driving

and reverse, and pulleys of different sizes for the two functions, instead of trains of gears. (6) Employing a large " bull wheel " for driving the table rack instead of a small pinion. (7) A vast extension of electric driving, with a corresponding multiplication of speeds, reverses, and feeds effected by switches. In consequence of these improvements, modern planing-machines hold their own in face of the keen rivalry of the plano-milling machines that operate on the same classes of work.

An example of a motor-driven planer is given in fig. 61. Taking 84 in. by 84 in., a 45-h.p. motor is required. It is one of a series by the Cincinnati Planer Company of Cincinnati, Ohio, U.S.A. It is termed a " rapid power traverse machine ", because each tool-head is moved rapidly from one position to another with power, derived from the motor mounted on the arch, instead of slowly by hand. Power is transmitted down through a splined shaft to a gear box at the side, provided with lever handles. Forced lubrication is supplied to the table vees. The table is boxed, and open at the sides so that dirt and chips can be drawn out.

DIVISION VII

Gear-cutting Machines.—Broadly all these fall under one of two groups. In the first the teeth are shaped directly or indirectly from a pre-existing form: directly, when the cutter has the section of the tooth space; indirectly, when a reciprocating planer arm carries a single-edged tool, controlled in its lateral movements by the edge of a former having the desired tooth curves to an enlarged scale. This method is suitable for all teeth, whether with single curves (involutes), or double curves (cycloids), and spurs or bevels. But, since the degree of accuracy obtained depends on the accuracy of the form, it is open to error. Though this may not be wholly eliminated, the gears so made are good enough for most commercial manufacturers. But they do not meet the very exacting demands of the high-speed gears used in automobiles and the best machine-tools.

In the second group the teeth are generated from the basis of the involute rack-tooth with straight sloping sides. A cutter having the section of a rack-tooth is used for generation, or one flank only of a rack-tooth, or several complete rack-teeth combined in one cutter, or, a pinion-like cutter, is generated from a rack basis, or a hob—a worm, with teeth of rack section, is fluted in milling-cutter fashion. In some machines the rack-tooth is not embodied in the cutter at all, but in the mechanism of the machine itself by means of " roll cones " in one design, and in another by certain controlled movements of slotted links.

Pressure Angles.—In order that all generated involute teeth shall mesh together, the pressure angle must be the same for all. This corresponds with the diagonal path of contact of the teeth to which the sides of the rack-teeth on the pitch points are normal. This is $14\frac{1}{2}°$ in the B. & S. system, the one until recently almost universally adopted. Its disadvantage is that small pinions are much undercut below the base line, to

oid which the rack-teeth in this system are slightly rounded, and the :ms of the cutters for pinions below thirty teeth have two curves instead one. Undercut can also be prevented by increasing the length of the dendum of small pinions. But other views now obtain, chiefly in conse- ence of the growth of generating methods, of the increasing employment the short "stub" teeth, and the desire for the closest approximation to ıthematical accuracy. Pressure angles are now increased to 18°, 20°, and en 25°. Gears can thus be produced without undercut down to twelve :th.

Machines using Form Cutters.—The type of these using rotary tters is the Brown & Sharpe. One group is used for spurs only, another :ludes the cutting of bevel gears. Later machines include provisions for ıltiple cutting. Form planing of spur and bevel gears is represented by : Gleason machines. These are made to be pitched by hand or automati- ly.

Machines for Shaping Gear Teeth.—The "Bilgram" was the ginal machine. It is now made for shaping spur as well as bevel teeth. ıis, and the Robey-Smith, employs planing tools, the movements of which : controlled by links. The Fellows machine cuts spurs, internal gears, i helical teeth. It employs a pinion-like cutter. The Sykes machine ploys two cutters, which operate simultaneously. They produce spur i helical teeth. The Gleason planer shapes the teeth by means of a yoke, the inside of which a segment is bolted which has the same angle as that the gear to be cut. The Sunderland machine cuts spurs and spirals, ng a reciprocating cutter containing six rack-teeth. The machines that .pe by means of hobs, cut spur, spiral, and worm-teeth.

DIVISION VIII

Grinding Machines.—Grinding has invaded the old territory of ning, boring, and facing. The lathe is now often a mere satellite—a .ghing, a first-operation machine, playing second fiddle to the grinder. cut is taken with a coarse feed that leaves marked spiral ridges on the face of the work. Then the grinder performs the second operation, nely, that of fine-finishing to precise limits. The lathe reduces with ater economy than the grinding wheel, but the latter imparts a finish in ıere fraction of the time that would be occupied by the turner in producing precise results. When machining allowances are slight, the grinder takes rge of the entire work. It is not necessary to pickle, as it is when milling :ers have to remove small amounts. The grinding wheel can operate h allowances of $\frac{1}{16}$ in. or less, which would give trouble to the lathe man) has to get under the skin.

Cylindrical Grinding.—This represents by far the largest volume of 'k done. The common method, to which there are exceptions, is to ıte the wheel and the work, and to traverse the wheel. The object of traverse is to get the maximum amount of duty from the wheel, and to

retain its truth as long as possible. To use a traverse feed only slightly less than the width of the wheel is more economical than to employ a feed that bears a small proportion to the width of the wheel. The peripheral speed of wheels is usually about 5000 ft. per minute, that of the work from 20 to 25 ft. The wheel speed is constant, that of the work is changed when desirable for making differences between roughing and finishing. Chatter and vibration are prevented by the employment of a large number of back steadies.

Surface Grinding.—This has been largely favoured by the employment of the magnetic chucks. These hold flimsy and awkwardly shaped pieces, which would give vast trouble if clamped on work tables. Reinforcements in the shape of stops and rings are necessary to prevent side-slip. A large number of small pieces can be held and operated on thus. Fixtures are also largely employed. The machines are built in two types, one in which the work table has linear movements, the other with rotary motions.

Machines for grinding cylinders, for form grinding, and those for tools and cutters include a large number of designs. The machines for grinding the cylinders of automobiles and gas-engines have developed with startling rapidity. The spindles have a planet or eccentric motion, so that while they are revolved at high speeds they are rotated slowly in a circular pathway, the diameter of which is increased to impart the feed. The work is carried on a table that can be adjusted transversely to bring bores in alignment with the wheel. The work table is fed towards the wheel with changes of travel for roughing and finishing cuts. Wet grinding is provided for by a pump and tank and pipe.

Continuous Grinding.—This relates to the treatment of numbers of small pieces arranged in tandem, or in a circle, to be ground with face wheels. Much of this work is done on magnetic chucks or in fixtures. The more awkwardly shaped and the smaller the pieces are, the greater are the economies of continuous grinding. Often the choice lies between this method and that of milling done on lineally or circularly moving tables.

CHAPTER V

The Shops

DIVISION I

Organization.—This must be based on a rigid cost system, from which the price of work in all its stages can be ascertained, and leakages detected from day to day. The old method of adding men's time in the aggregate and lumping contingent expenses and profits on that is no longer followed in competitive firms.

In order to fix costs at all stages a routine system is essential. For this

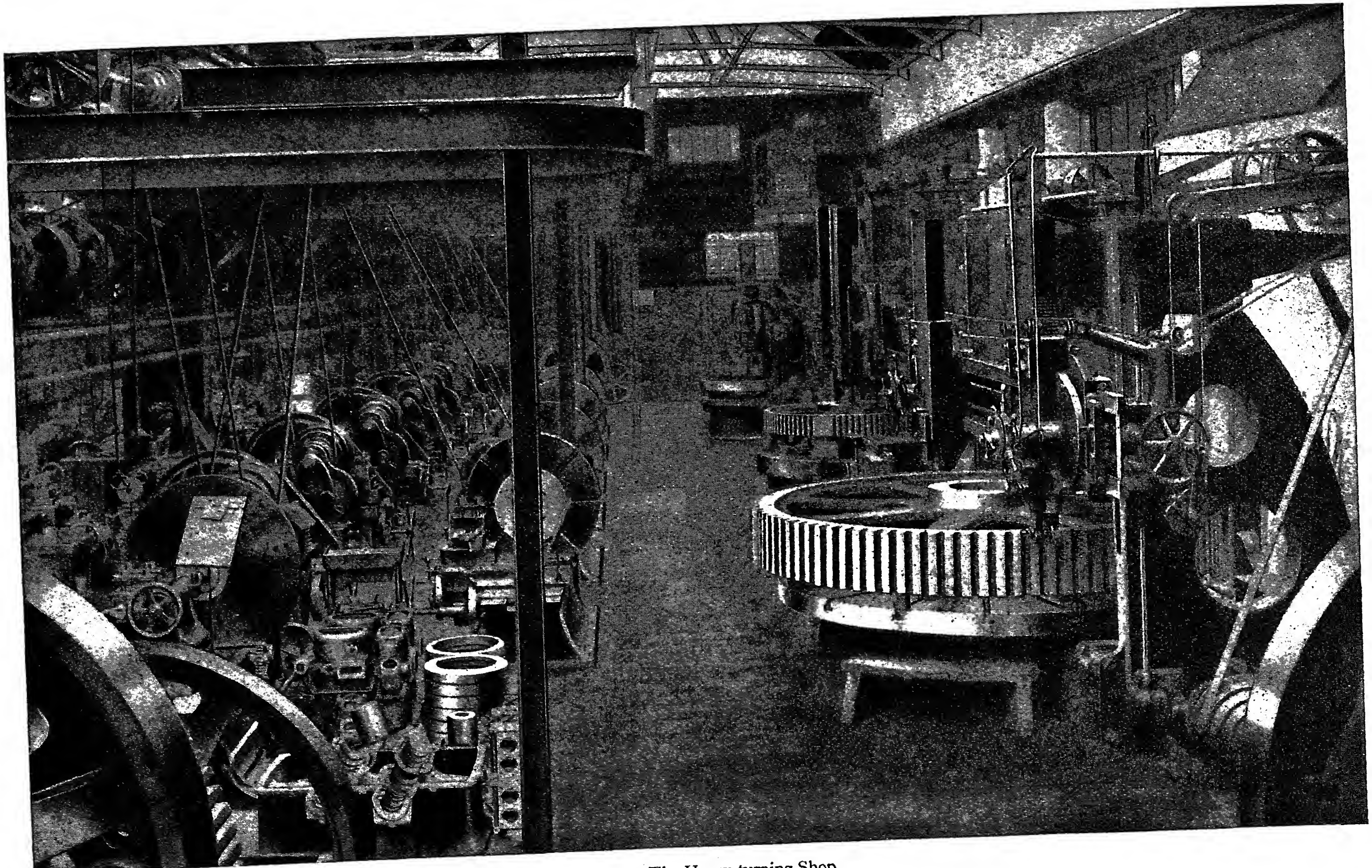


Fig. 62.—The Heavy-turning Shop

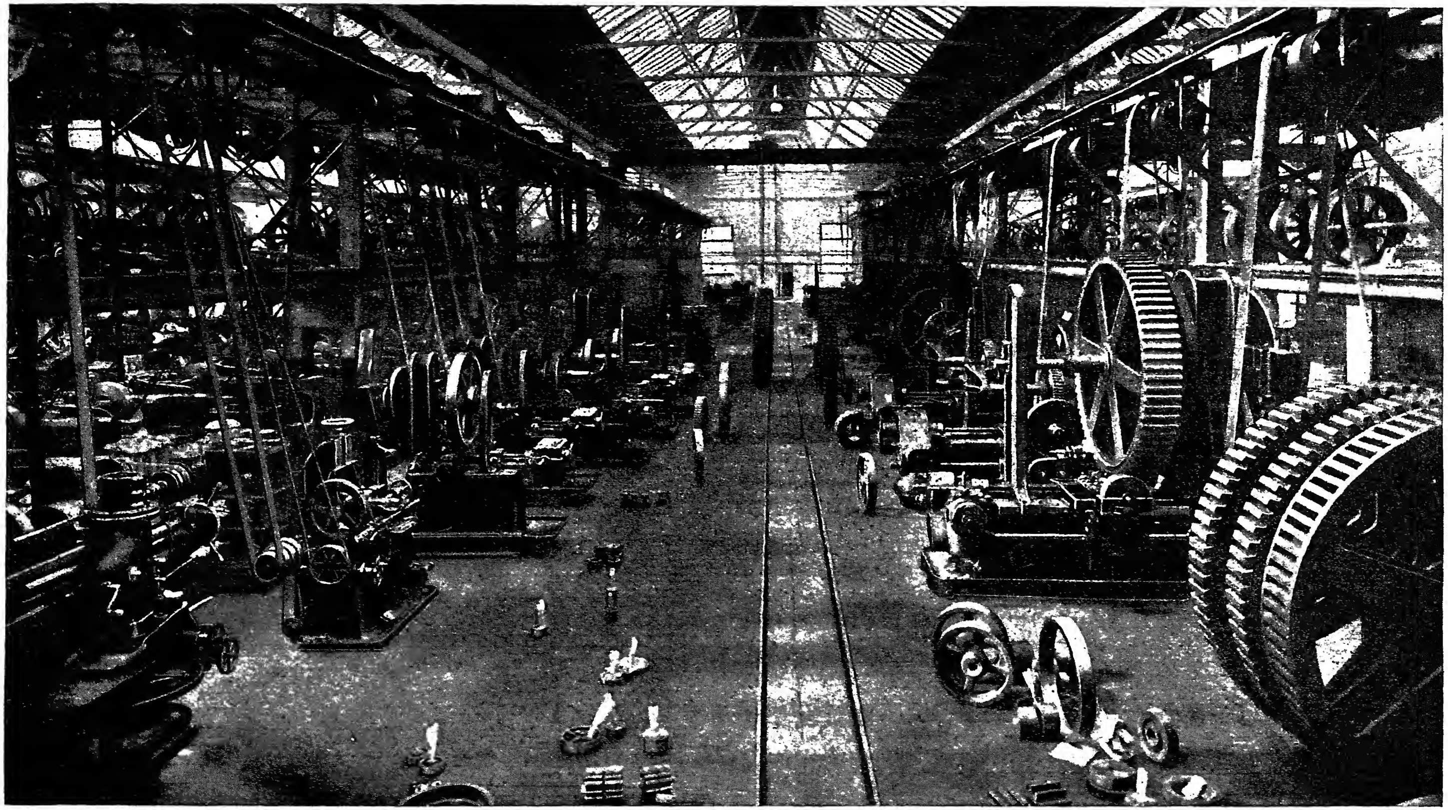


Fig. 63.—Spur Gear-cutting Department

an intimate knowledge of the nature and scope of the operations performed on hundreds of machine-tools is necessary. This devolves on the shop manager, and on the foremen who have charge of the groups of machines, as lathes, automatics, planers, gear-cutters, milling machines, grinders, and so on. Each foreman must know the capacities and limitations of each of the machines in the group of which he has charge, and must see that they are operated to the fullest advantage. He will consult and discuss with the shop manager respecting the best methods of machining certain articles. The manager will decide the question of economies that may result by the transference of work from one group of machines to another, as from lathes to turret lathes, from planers to milling machines, from lathes to grinders, and so on. The foremen and manager jointly consider the question of the design and employment of fixtures and jigs, and the relation of the expense which they bear to the product. Detailed drawings are made in the office from sketches supplied.

When the methods of machining have been determined, the details are put on a definite basis by the foreman or the rate-fixer. Sketches are prepared, or cards are written, stating precisely the nature and sequence of the several machining operations involved, the tools to be used, the speeds and feeds, and limits. Generally it is possible, as the work proceeds, to effect slight speeding-up, which on a piece-work basis, or a bonus system, is to the advantage of the machinist. But it does not lie with the attendant to make changes in the general routine previously determined. That can only be done by suggestion, with the consent of the foreman, or manager.

This organization includes all details. The grinding of tools of all kinds is done in the tool-room, and they are checked out to the men, and returned when they have become dulled with use. Gauges, jigs, and fixtures are treated similarly, and they are corrected or renewed in the tool-room. In this system nothing is tabulated by name. Every item, however insignificant, has a number, or a letter, inserted on the drawings, and is checked out and in by that.

The Tool-room.—This is a necessary growth, consequent on turret practice, and on the employment of the multiple-edged cutters used on milling machines, gear-cutters, and elsewhere. The set-up of boxes of tools for turret work entails elaborate constructions and delicate adjustments. The grinding of cutters can only be done on universal machines. Drills are ground on machines. The standardized grinding of single-edged cutting tools is done on machines. These functions are relegated to the men in the tool-room, who also construct the smaller jigs and fixtures. Hence the tool-room is a machine-shop in miniature, a microcosm complete in itself. It contains a few machines of every class, in which universal designs are in evidence, so that, having castings and forgings and bars supplied, the whole of the work of tool-making in its widest sense is performed within its precincts, and tools are ground, repaired, set-up, and kept in working order, ready for use in the shop.

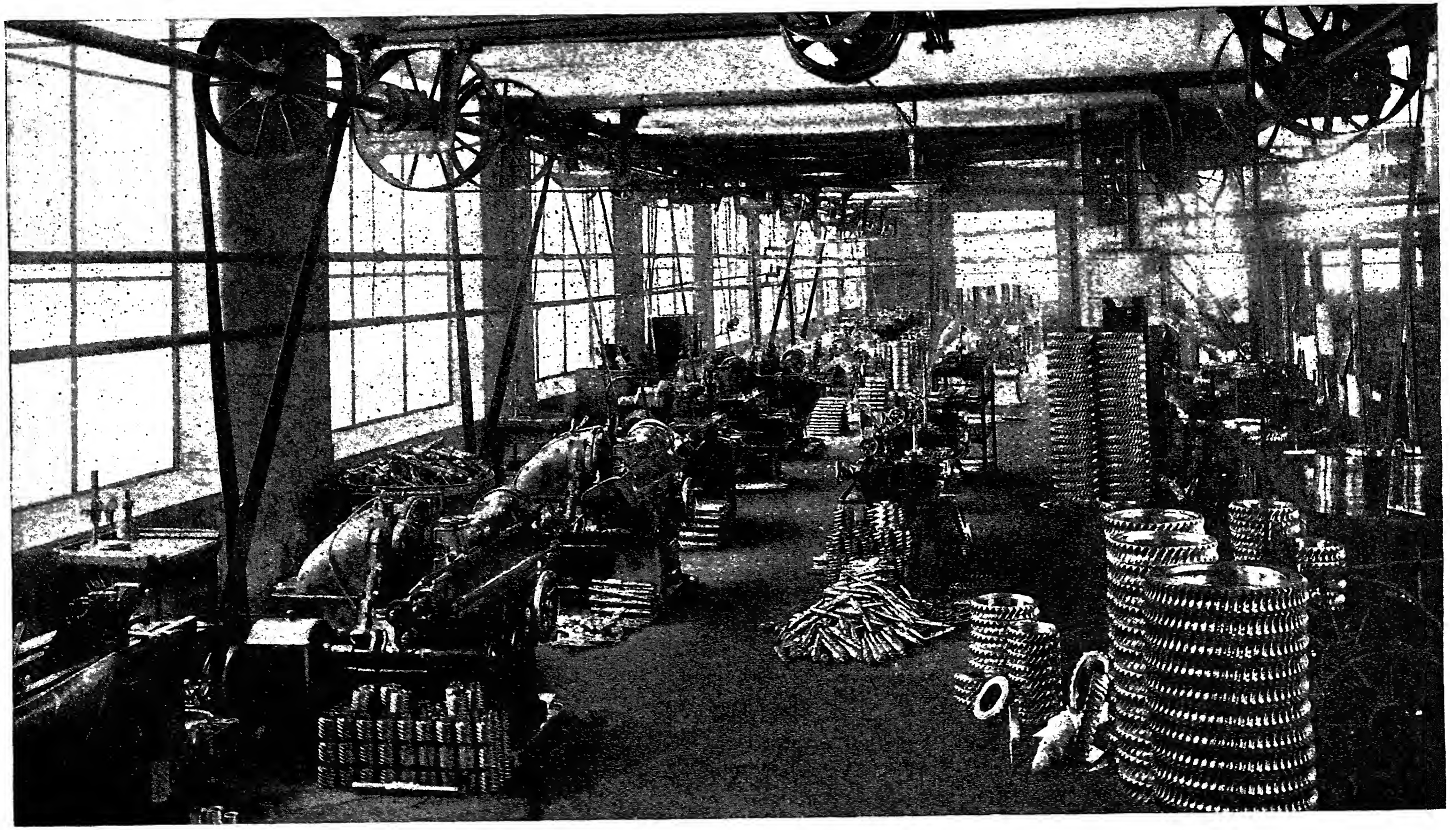


Fig. 64.—Department for Milling and Testing Worm Wheels

DIVISION II

Illustrations of Shops.

1. *Messrs. David Brown & Sons (Huddfd.), Ltd., Lockwood, Huddersfield.*—This is a large works, occupied solely in the production of gear wheels. The extensive shops are laid out on the ground floor exclusively, and all are arranged in parallel. The works are self-contained, including pattern-shop, foundry, smithy, and hardening-shop. There is a heavy machine-shop, and a heavy erecting-shop. The principal sectional departments are: the raw material stores, the tool stores, the cutting-off, the light fitting, and milling, automatic, double helical and bevel gear, spur, worm, and spiral departments. Also heavy and light turning, planing, boring, drilling, capstan lathe, and grinding departments, the tool-room and inspection. The bays range from 120 to 310 ft. in length. They are served with overhead electric travelling cranes. Skylights in ridge roofs give ample light, and arc lamps provide artificial illumination. The machines are all driven electrically, the smaller in groups, the larger with separate motors.

Fig. 62 shows the heavy-turning shop. Heavy boring and turning mills are seen on the right, and a number of chucking lathes on the left, served with an overhead runway and pulley blocks. Fig. 63 is a view taken in the spur gear-cutting department. A catholic selection of machines is apparent, They include the Gould & Eberhardt, the Brown & Sharpe, the Sunderland, and the Fellows gear generators. Much of the work is of a massive nature, requiring the service of the overhead travelling crane. Fig. 64 is the shop in which worm and spiral gears are milled and tested. The machines used were designed and built by the firm. The machines for grinding worms after cutting and hardening are also made by Messrs. Brown. The heads of the grinding wheels are adjustable to suit the gear angles. In the general grinding-shop, cylindrical and vertical spindle machines are installed, and trays disposed down the centre hold the work.

2. *Messrs. A. Harper, Sons, & Bean, Ltd., Dudley, Worcestershire.*—The works of this firm at Tipton are built for the construction of automobiles, the various departments of which are illustrated by the photographs following. Precision tools are made at Dudley, and drop forgings and pressings at Smethwick. The foundry is at Tipton.

Fig. 65 is a view in the milling department. An Ingersoll machine occupying the centre of the shop is dealing with a row of crank cases. It is machining the timing cover face, the cylinder face, and the ends of the feet simultaneously. Two vertical machines on the left mill the sump face, and the magneto, starter, and lighting faces respectively. In the foreground at the right is seen the milling of the vertical face for the magneto cradle. These machines are laid out in line, arranged for each operation in sequence, and the component parts are passed along to the machines on a roller type of conveyor, with ball-bearings, occupying the centre of the shop.

Fig. 66 shows a line of seven multiple spindle "Natco" (National Automatic Tool Company) drilling-machines. The third, fifth, and seventh—the

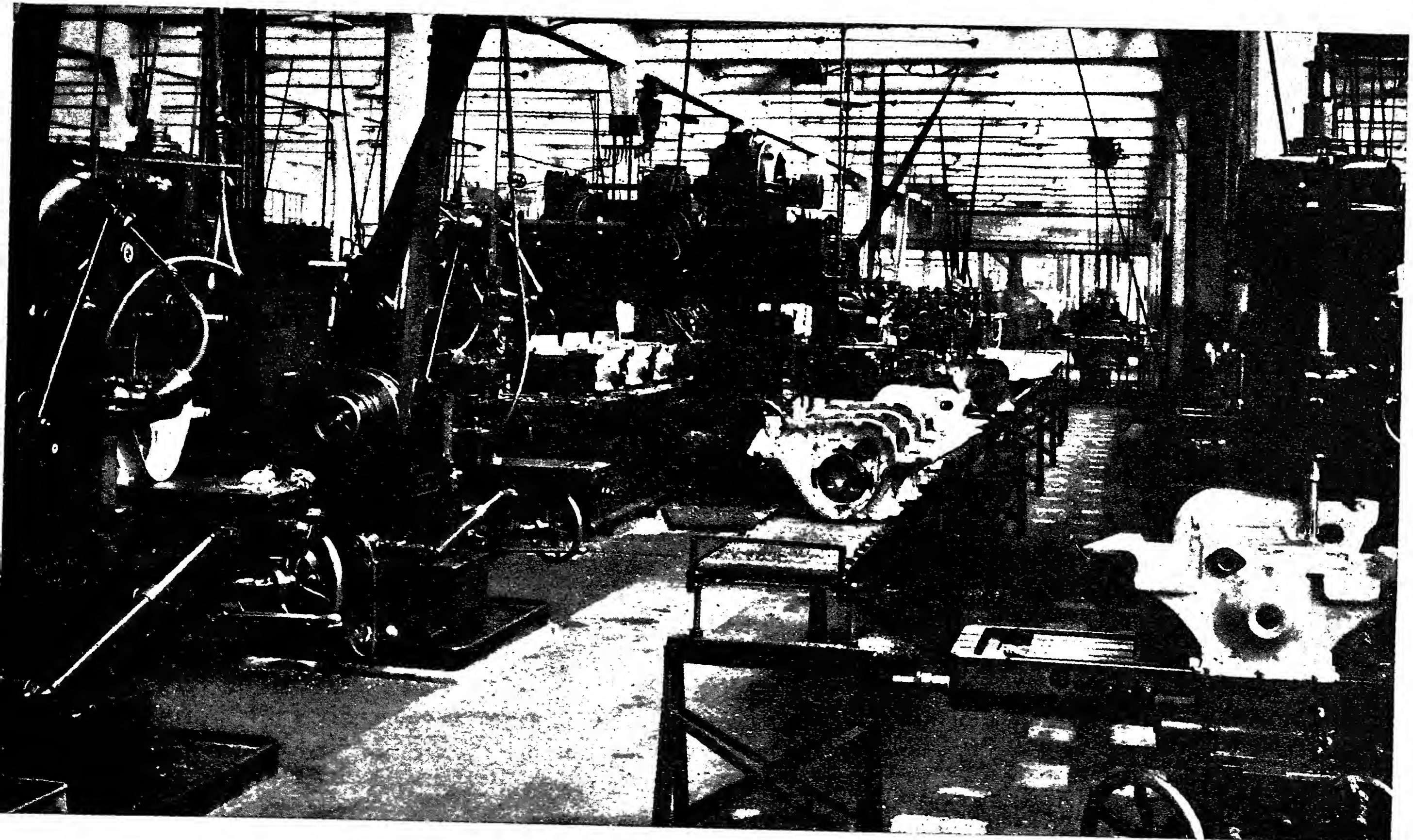


Fig. 65.—Milling Department for dealing with Crank Cases

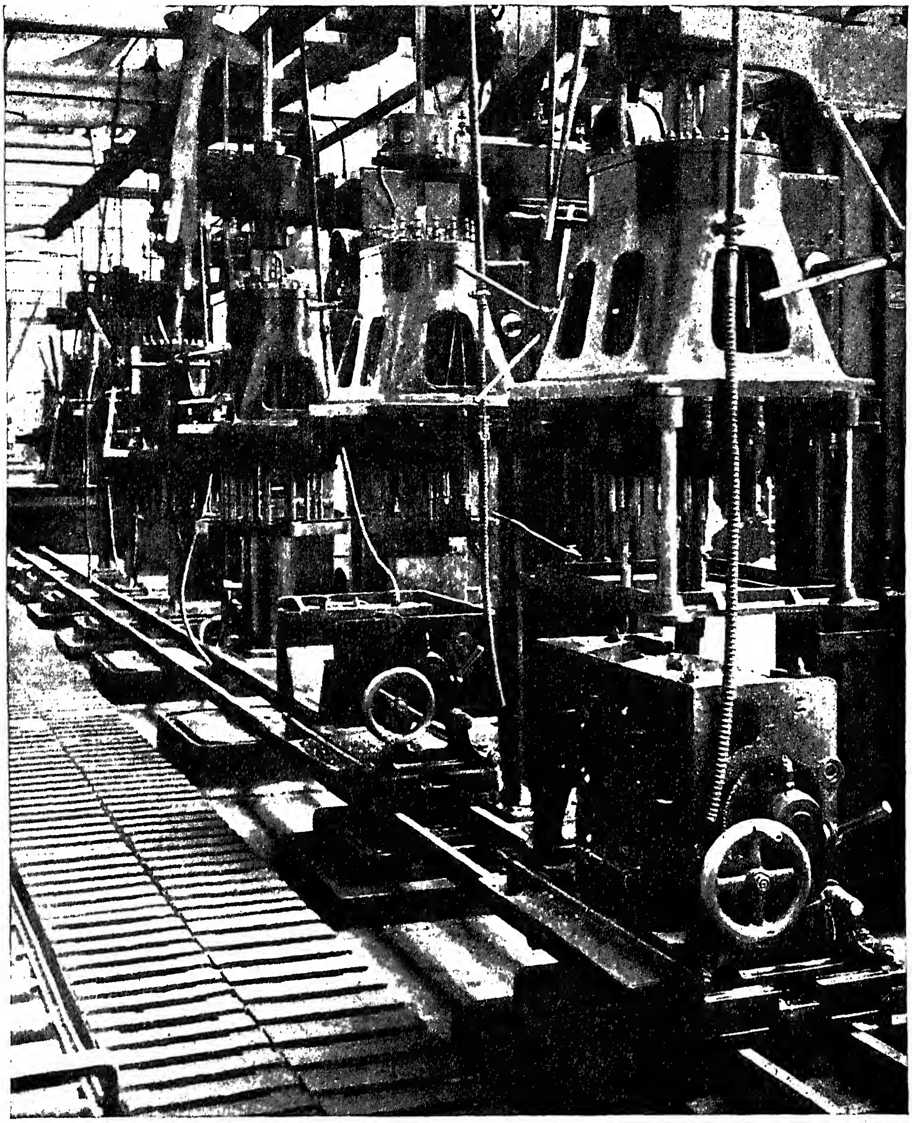


Fig. 66.—Crank Cases, in Fixtures carried along Tracks, being Drilled and Tapped under "Natco" Multiple-spindle Machines

foremost—are being used for tapping in all 44 holes in the crank case, and the others drill between them 72 holes. The method used for locating the case is the truck fixture on trunnions, transported along the tracks. The case is loaded at the beginning of the track, and is unloaded after passing under all the machines. The trucks run on to turn-tables, and are returned by way of a similar track at the rear. Two or more fixtures are used. As each operation is completed the chips are blown out by compressed air.

Figs. 67 and 68 are two views of the methods employed in milling the

cylinder faces on an Ingersoll machine. Four spindles are operating together on two components at a time. On the left side the crank case and manifold

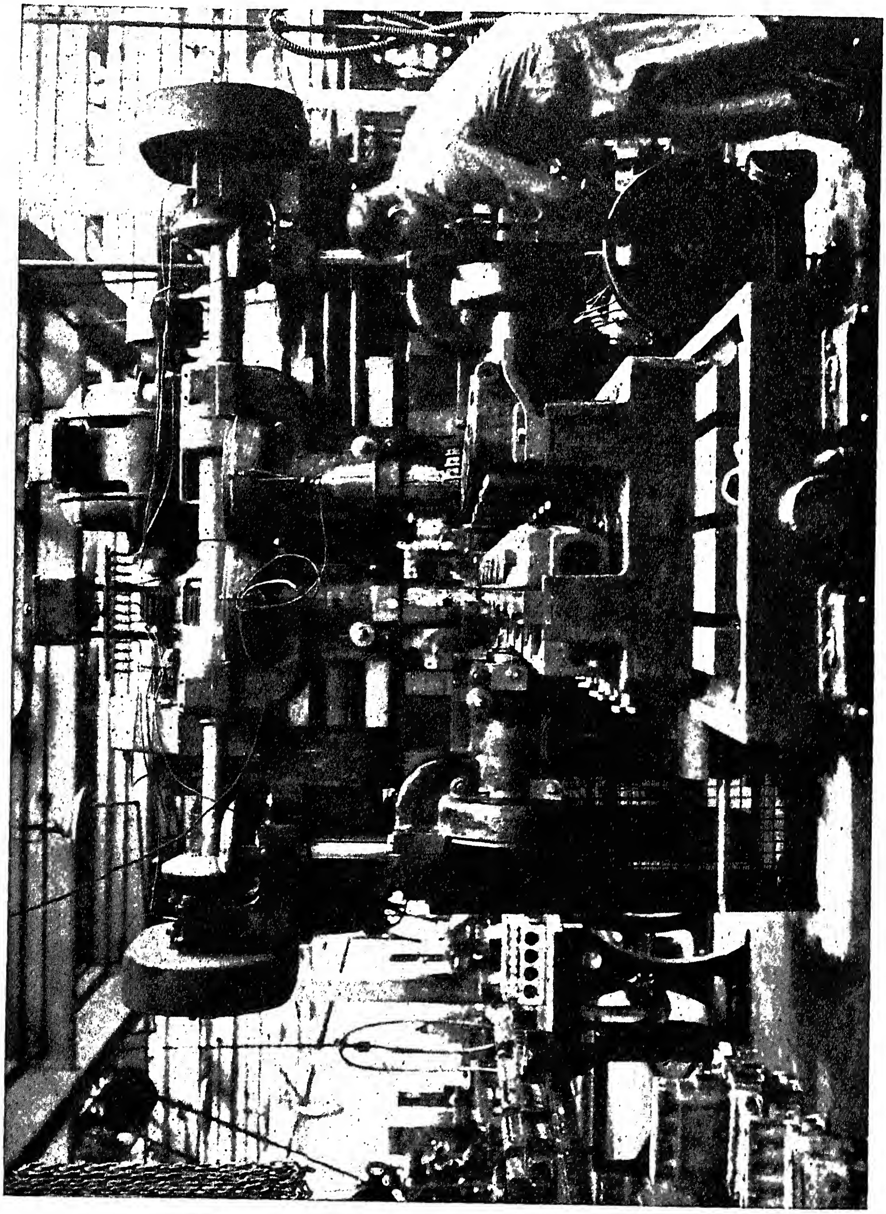


Fig. 67.—Twelve Motor Cylinders in a Fixture being Milled on an Ingersoll Machine. View from the end

faces are machined—these two faces being used as registers for machining the top face, and the inspection cover faces on the other side of the machine. The fixture will take twelve castings, so that it will be seen that six are completed at each setting.

Fig. 69 shows an assembled frame in position in a frame-drilling jig. Any errors in the frame are taken care of by the locations being made self-centring and compensating. Two Hammond double-arm drilling machines

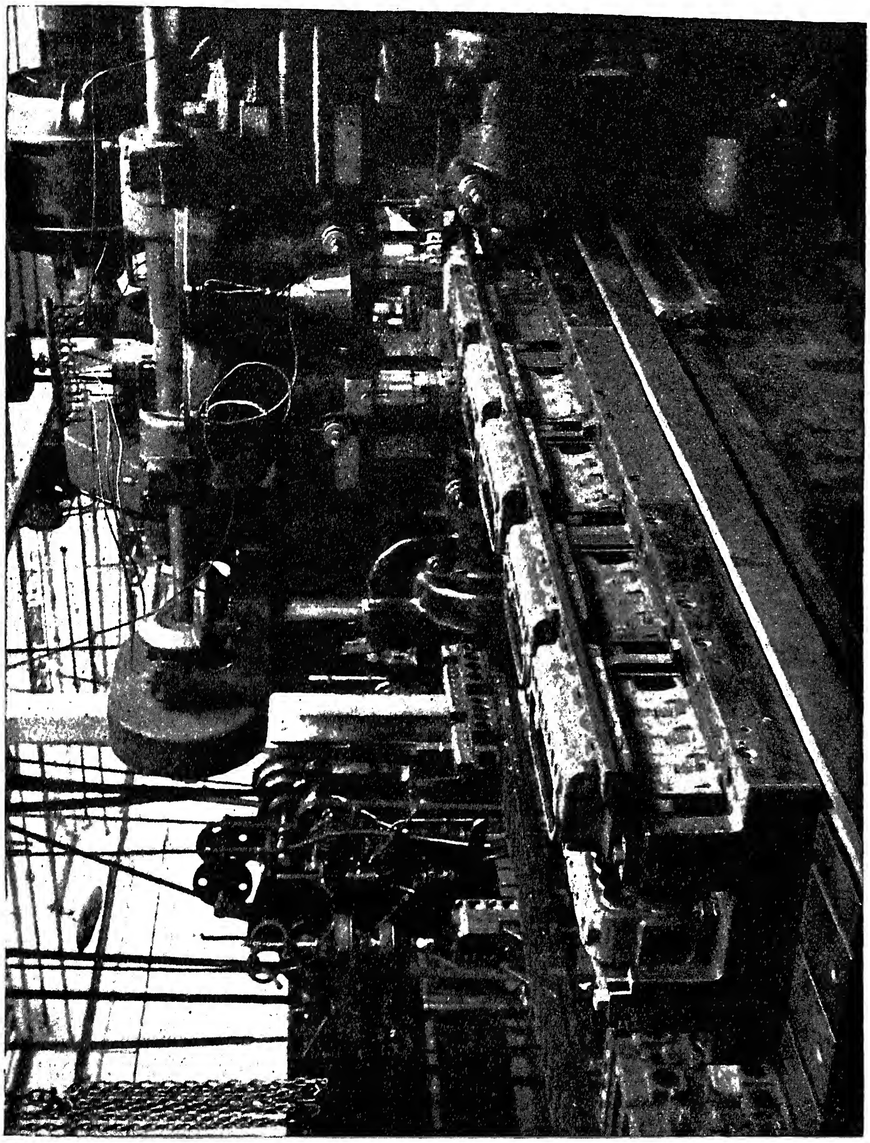


Fig. 68.—Twelve Motor Cylinders in a Fixture being Milled on an Ingersoll Machine. View from side

cover all the holes, the machines being bolted on channel irons. Special shanks are used for all the various drills to bring them to their correct levels, and thus avoid vertical adjustments of the machines. The shanks are used in conjunction with quick-acting "Gronkvist" Swedish drill chucks, which allow the drills to be removed without stopping the machine. The drilling

Fig. 69.—An Assembled Frame being Drilled in a Jig Fixture

jig consists of two cast-iron trunnions, on which swing two indexing plates. Channel irons which connect these plates carry all the bush plates, and quick-acting clamps, the compensating beams, and locations. The construction is such that the revolving parts are light, yet rigid, so that no deflection can occur during drilling. The whole jig can be revolved easily, and indexed to allow for drilling from four sides. Foot treadles are arranged in convenient positions for starting and stopping the machines. The result of these economies is that the 112 holes in the frame are drilled in twenty minutes.

FITTING AND ERECTING OF HEAVY MACHINERY

BY

G. M. S. SICHEL, B.Sc.

Fitting and Erecting of Heavy Machinery

The assembly and erection of heavy machinery of all types calls for not only the skill and care which the handling of large plant requires, but, to a very large degree, for the judgment which is partly intuitive and partly the result of wide and all-round experience. So many problems arise in the erection of plant on site, as compared with its erection at the makers' works, where all the usual facilities exist, that success or failure depends very largely on the ability to size up a difficulty correctly, and then devise ways and means of producing the best possible results. It is not possible, therefore, in an article of this kind, to give complete directions for the assembly and erection of all kinds of heavy plant, as the conditions to be met with vary so greatly; the aim of the article will be to deal with the kind of problems that arise and the various means taken to meet them. It will probably be conceded that, if the problems which arise in the erection of a large steam-turbine electric generating set and condensing plant be considered, the ground will cover most of the problems that arise when handling less complicated plants. The article will deal, therefore, with a plant of this description, and some general notes will be added on the application of the principles to the erection of special plants.

Foundations.—These are almost invariably made of concrete nowadays, though in certain cases brick is used for cheapness and where the weights to be supported are not very heavy and are not subjected to shock. In general, it is advisable to make the lowest part of the foundation block in the form of a concrete float or raft on which the main foundation block is built. The dimensions of this concrete raft depend on the nature of the subsoil; where this is soft or friable, the area of the raft must be correspondingly large in order to lessen the weight, per square foot on the raft, of the superimposed machinery. Where the subsoil is particularly soft, it will probably be necessary to drive a large number of piles first, round the heads of which the concrete raft is built. It should be the first duty of the engineer in charge of erection of machinery to satisfy himself regarding the suitability of the foundations and the subsoil. In general, the foundations are provided by the customer to the drawings of the contractors who supply

and erect the machinery, but no contractor will accept responsibility for the foundations which are built to his drawings, as he cannot be expected to be familiar with local conditions, or the peculiarities of the subsoil.

The datum line, or level from which all vertical dimensions are taken, is usually the finished engine-room floor-level, and the foundation-block height is carried up till, with an allownace of 1 in. to 2 in. for packing plates

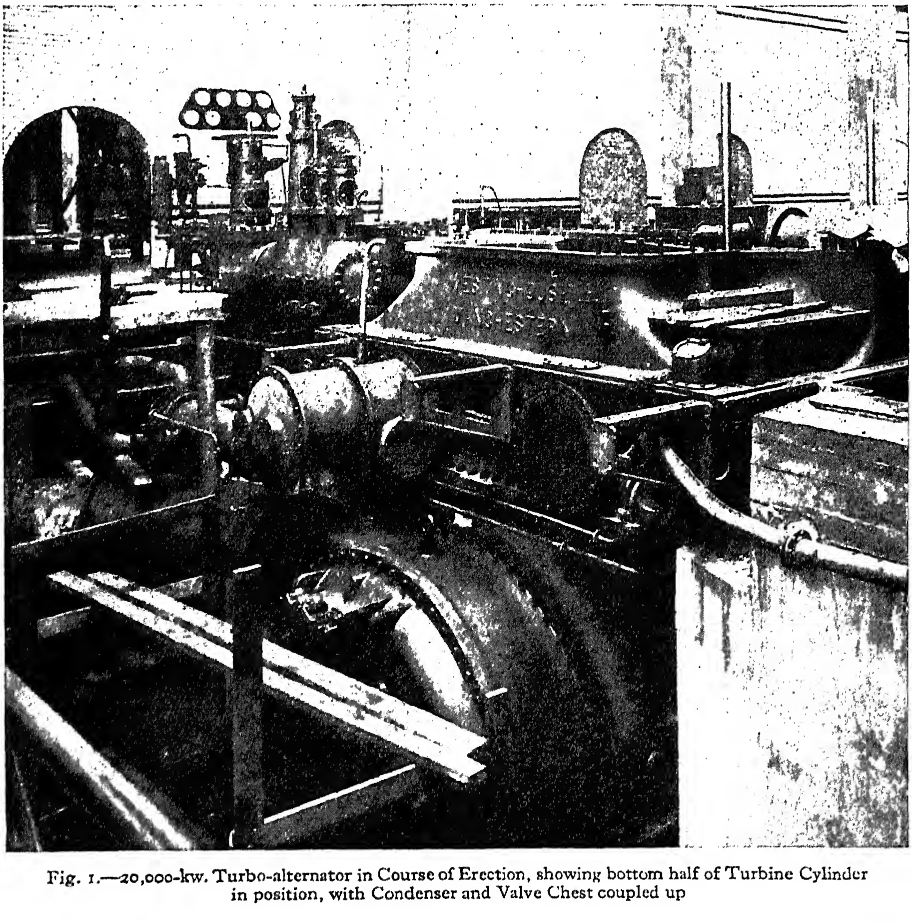


Fig. 1.—20,000-kw. Turbo-alternator in Course of Erection, showing bottom half of Turbine Cylinder in position, with Condenser and Valve Chest coupled up

under the bedplates, the top of the latter is at the required height with reference to the datum level. In some cases it is becoming the practice to build short pieces of H-girders into the top of the foundation block to support the bedplate; these girders are spaced every 3 ft. or so, and are carefully levelled so as to present a smooth metal surface on which to level up the bedplates. Where provision has to be made in the foundation block for foundation bolts, it is advisable to make the holes big enough to allow at least 2 in. lateral movement of the bolt in every direction; this allowance will take care of any inaccuracies between the drawings of the bedplate and the actual

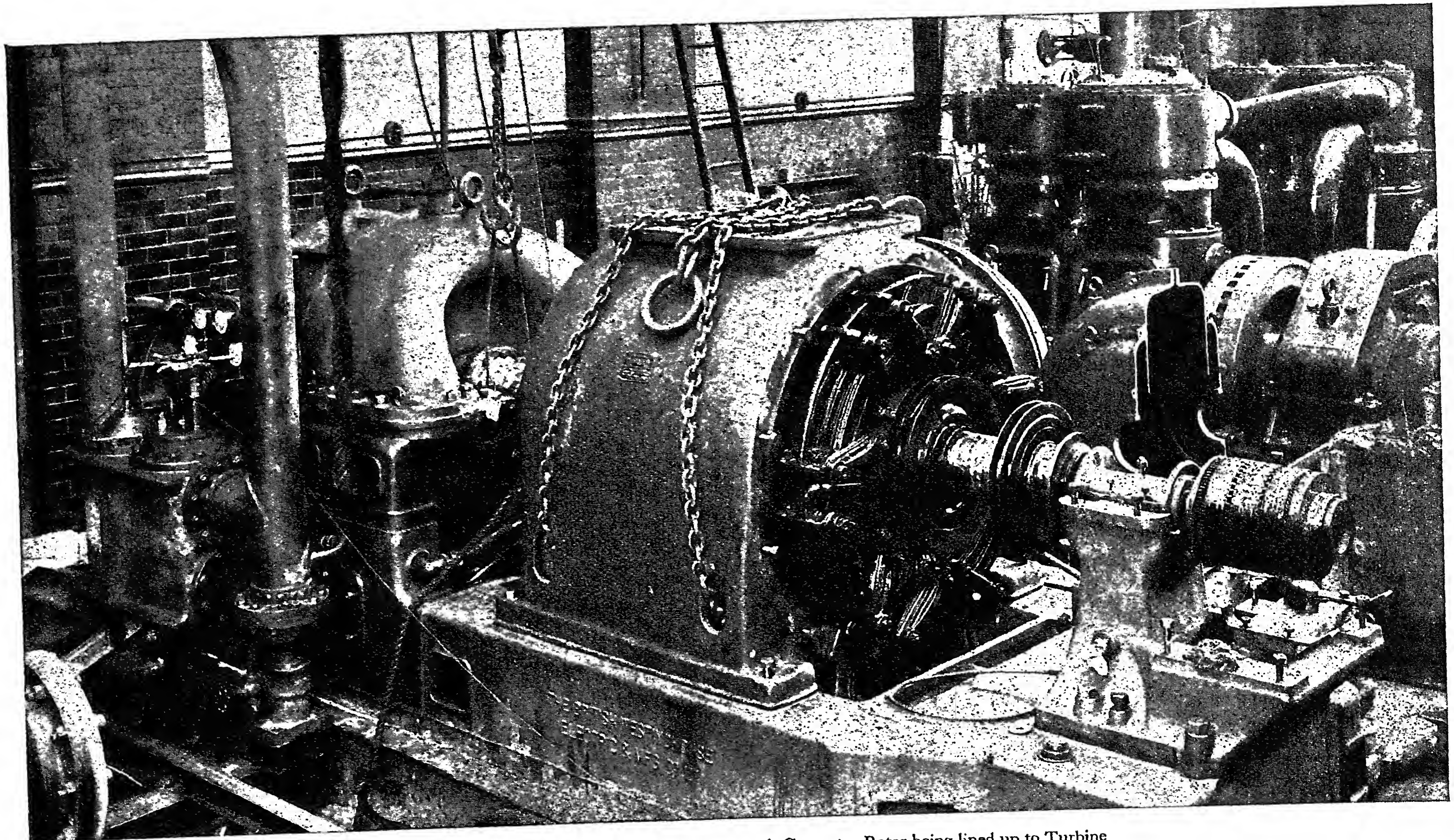


Fig. 2.—1000-kw. Turbo-alternator Set partly erected, Generator Rotor being lined up to Turbine

casting, more particularly as regards the spacing of the holes for the foundation bolts. As it is the general practice to grout-in bedplates, care should be taken to see that the top surface of the foundation block is left rough, so as to allow the grouting material to obtain a grip or bond with the foundation. Where short H-girders are built in, as explained (p. 244), the level of

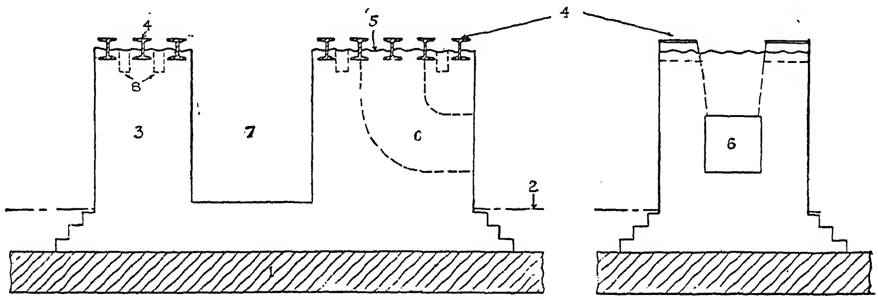


Fig. 3.—1, Concrete float. 2, Ground or basement level. 3, Foundation block. 4, Short steel girders built in. 5, Surface of block left rough for grouting. 6, Air inlet to generator. 7, Space for condenser. 8, Foundation bolt holes.

the concrete should be left at least 2 in. below the top of the girders, in order to allow the grouting material to obtain a good grip of the girders.

Bedplates.—Before putting the bedplates in position for carrying the prime mover and generator, care should be taken to see that any heavy parts of the plant, which are situated underneath, are put in position first, in order to obviate trouble and difficulty later on. In the case of very large steam condensers this is essential, but where the weights are not excessive,

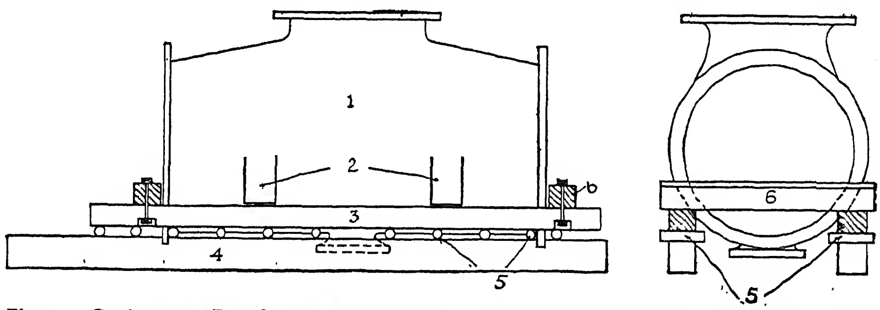


Fig. 4.—1, Condenser. 2, Feet of condenser. 3, Wood baulk not necessarily secured to condenser feet. 4, Wood baulk or steel girder for runway. 5, Steel rollers. 6, Cross batten to tie together supports (3).

and the dimensions reasonable, the condenser may be slid in under the turbine, after the latter has been erected, and then jacked up or lifted by the crane, one end at a time, and packed up till in its final position. To do this, it will probably be necessary to build a suitable cradle, or support of girders or timber baulks, on which to rest the condenser during this operation.

Let us assume, then, that the condenser and other heavy parts, e.g. atmospheric exhaust valve and pipes, &c., have been placed approximately in position. The turbine bedplate is then put on the foundations, prefer-

ably on steel packing plates at least 1 in. thick, placed underneath the heavier parts, so as to leave a gap below the soleplates, which will facilitate the insertion and drawing-out of wedges or flat packing plates used in levelling up. The bottom portion of the turbine cylinder can then be placed in position and levelled up, both axially and transversely.

It may be accepted as a good general rule that, before placing together two machined faces, the faces should be lightly rubbed over with a smooth, flat file, more particularly all round the edges of the machined faces. This not only ensures that the faces are clean and free from burrs (particularly round the edges of drilled holes), but it also immediately shows up any bulges or bumps on the faces. These burrs are often caused by the links of chain slings pressing into the machined faces, when chains are used for lifting the castings. Instead of putting down the bedplate first, the bottom half-turbine cylinder may be put directly on the bedplate, bolted down, and the whole then lifted in one piece, where the capacity of the overhead crane or lifting tackle is large enough. In the majority of steam-turbine plants, guide or director keys are provided between the bedplate and the cylinder, which prevent movement in a transverse or lateral direction, while allowing free movement in an axial or vertical direction. This is done in order to allow the cylinder to " breathe " or expand and contract with varying temperature, without upsetting the alignment of the set. It is important, therefore, to see that these guide or director keys are not only properly fitted, but when fitted are secured against the possibility of working out. The turbine bottom half-cylinder and bedplate may now be levelled up; it is often found when levelling up large castings that if the piece be levelled, say in a transverse direction, by means of a level applied to one side of the casting, and the level be then tried in the same direction on the other side of the casting, it will be found to be out of level. This is nearly always due to the casting having " sprung ", due to internal strains in the casting easing themselves, more particularly when the skin is broken by machining. Another cause is the manner in which the casting has been bolted or cramped down on the boring-mill or planer-table, when being machined. If the casting has been sprung before machining, then, when the bolts or cramps are released, the casting will spring back, and the result will be that the machined faces are not true. This difficulty is got over by placing a steel or stiff wood straight-edge right across the bedplate or cylinder, and putting the level on the straight-edge and setting the casting or piece level in this manner. The levelling up is done by inserting steel wedges, preferably 3 in. wide, under the soleplate, and, when wedged up, adjusting the height of the parallel packing pieces. In this way a true surface is prepared (represented by the top of the packing pieces), on which the bedplate may be moved laterally without upsetting the level of the piece. The next operation is to check the height of the centre of the turbine shaft or spindle above the engine-room floor-level; if the centre is too low, then it will be necessary to increase the height of all the parallel packers by the amount by which the centre is too low. Conversely, if the centre is too high, the thickness of the packers

will have to be reduced, either by the use of thinner packers or by having the packers machined. Having thus levelled, at the proper height, the bedplate and bottom half-cylinder, the next operation is to set the cylinder central on the axial centre line. For this purpose it is usual to use a length of fine piano wire, stretched tightly by means of weights between the two outer pedestals. The wire is very carefully centred at the extreme edges of the bearing pedestals, and the bottom half of the cylinder, plus bedplate, is then jacked over on the packing pieces below the bedplates, so as to bring it central on the steel wire. The final test is made with an inside micrometer, behind which is held a piece of white paper, in order to show clearly when the end of the micrometer is just touching the wire. This adjustment makes the cylinder right for position sideways and vertically. Its position endwise is usually taken from the centre line of the turbine exhaust, and this line, as well as the axial centre line, is determined beforehand for building up the foundations, and is retained for definitely fixing the position of the turbine.

When the piece is finally set, the level should again be very carefully checked, and if necessary readjusted, before the bedplates are grouted-in. There is a difference of opinion among engineers regarding the best time during erection for grouting-in the bedplates. Some men prefer to erect the whole plant complete before doing any grouting; others prefer to grout-in the bedplates immediately they have been finally set and checked over, and before any weight, e.g. other portions of the plant, is put in position on the bedplate. The arguments used in favour of the former method are, that if the whole plant is completely assembled first, any errors in the drawings, which might make it impossible or difficult to fit the various parts of the plant together, can be adjusted without cutting away the foundations or undoing a lot of work made permanent. Against this advantage must be placed the disadvantage of liability to spring the castings and soleplates, due to the concentration of the weight of the whole plant on the comparatively small area of the packing pieces between the soleplates and the foundation block. On the other hand, the number of cases where a complete plant has to be taken up and re-erected, due to some oversight in the layout drawings, is so remarkably small as to be almost negligible, and a good deal can be said in favour of grouting-in immediately the soleplates and main structure have been assembled and checked for position. The whole of the area of the underside of the soleplates is thus available for distributing the weight of the plant, and in consequence the liability to settle and get out of level is very much reduced; further, it is usually possible to make a very much more satisfactory job of the grouting-in process before the whole plant is assembled, on account of the greater freedom and space to get at the job when the bedplates and lower parts only of the plant are in position. Instead of using parallel packing pieces, which are left in and grouted-up, some engineers prefer to use steel wedges, about 3 in. wide and 3 or 4 in. long, tapering down in thickness from $\frac{1}{4}$ in. to nothing. The wedges are driven in under the sole plates until the latter are levelled up,

and, after the grouting has been run in and has set, the wedges are withdrawn. The use of wedges is a much quicker job than with parallel packers, but it is obvious that the contact of the wedge with the soleplate is more or less a line contact, as compared with the surface contact obtained with parallel packers, and it is therefore essential when using wedges that the soleplates be grouted-in before any weight is put on.

Care should be taken in mixing up the grout to see that it is thin enough to run easily under the bedplates; it should have the consistency of very

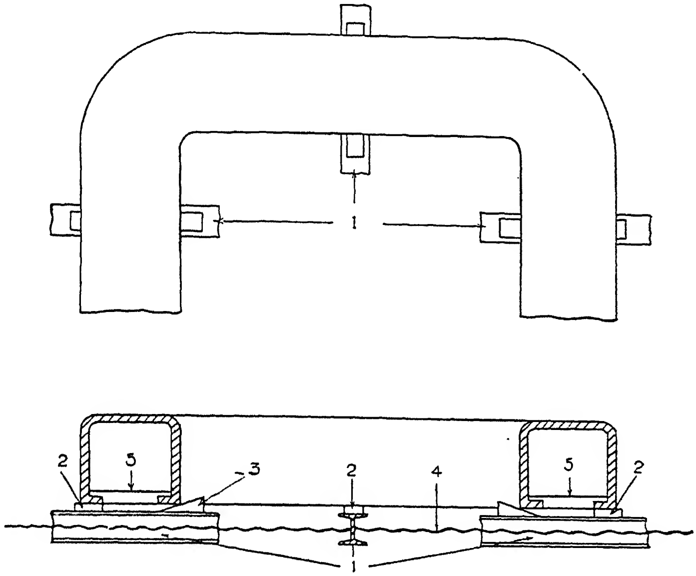


Fig. 5.—Bedplate in Position before Grouting-up, showing parallel packers with surface contact and wedges with line contact

1, Steel girders built in. 2, Parallel packers. 3, Wedges. 4, Top surface of foundation block, left rough. 5, Grouting level.

thin cream, and should preferably be more liquid than otherwise. The proportions of cement and sand used are as follows: one part by volume (bucket or barrow) of cement, two parts fine sharp sand. Before grouting-up, a dam of stiff cement, or of boards or bricks, should be built all round the bedplate to a height of 2 or 3 in. higher than the finished level of the grout, and the surface of the concrete foundations should then be thoroughly wetted with several bucketfuls of water, in order to prevent the water in the grout being rapidly absorbed by the concrete foundations. The grouting material is then run in, and, when the surface of the liquid is above the bottom of the soleplates, the grout should be well worked under by means of a short length of thin, flat iron (hoop iron 1 in. × $\frac{1}{16}$ in. thick does very well for this purpose). This should be continued till the level of the grout is about 1 to 2 in. above the level required when complete, to allow for contraction of the grouting mixture due to absorption of the water. It is frequently customary to add some thicker grout at the end of an hour or

so, after part of the contraction has taken place and the grout partly settled. With regard to the length of time required to set, this varies with the nature of the cement; some slow-setting cements take two to three weeks to set properly, but where ordinary cement is used in mixing the grout, and the depth of the grout is not great, sufficient setting should take place in a week. A simple test is to stab the surface of the grout with the tang end of a file held in the hand; setting should be allowed till the point of the file marks but does not enter the grout. It is usual to carry the grout up over the top of the bottom flange of the soleplate in order to secure a good grip; in some cases the whole of the hollow interior of the bedplate is run in solid with grout; in such cases it is advisable to have some holes drilled previously in the bedplate to let out the air, and allow the grout to fill the whole solidly.

When properly set, the dam of brick or wood is broken away, and the grout projecting from the side of the bedplate is dressed off. The holding-down bolts, which secure the turbine cylinder and bearing pedestals to the bedplate, should be carefully examined and adjusted, and dowel-pins between the cylinder and bedplate properly fitted. A word might usefully be added here on the use of dowels and holding-down bolts in such cases. Due to the wide range of temperature through which a steam turbine has to work, i.e. from the temperature of the atmosphere, when starting up, to the temperature of the steam when on load, and also on account of the high temperature throughout that may be reached, if the vacuum on the condenser is lost and the set goes over to atmospheric exhaust, the expansion and contraction or "breathing" of the cylinder and shaft may be very considerable, and amount to $\frac{1}{8}$ in. or $\frac{3}{8}$ in. in large sizes of plant. The amount of this expansion can be calculated from tables of the linear coefficient of expansion for various metals, though the actual movement may differ, in certain cases, from the calculated amount, on account of the shape of the casting, &c. Provision has to be made to allow this expansion to take place, and at the same time the cylinder, bearings, &c., have to be properly held down. It is usual, therefore, to definitely fix a datum level from which the vertical expansion and contraction can take place, and also to fix a definite transverse line from which the axial expansion and contraction can take place. The datum level for vertical expansion is naturally the top of the bedplate supporting the cylinder, and it is an advantage to have this level as near as possible to centre line of the shaft and cylinder, so as to make the expansion or "lift" of the cylinder top half equal to the downward movement of the cylinder bottom half, and so keep the cylinder under all conditions central, vertically, on the turbine spindle. In some turbines the datum level is several feet below the shaft centre line; in these cases it is usual when setting the turbine shaft to put it some ten-thousandths of an inch high, so that, as the cylinder expands or lifts with heat, it makes itself central on the turbine spindle. The transverse line for fixing the datum, from which the axial expansion takes place, is secured by means of two stout dowel-pins, one on each side of the turbine cylinder, set half in the cylinder feet and half in the bedplate. These dowels should be a nice tapping fit in order that,

while they definitely fix a line, the cylinder is free to expand along the dowels as it gets hot. These dowels are usually placed about midway along the cylinder length, and the expansion thus takes place in both directions from this line. In other cases, the dowels are fixed at the exhaust end of the cylinder, and the whole expansion thus takes place in the one direction, viz. towards the H.P. end. It is necessary, of course, to have a fixed point on the cross transverse datum line, so as to control definitely the direction of the sideways expansion. This fixed point is formed by vertical keys at both the H.P. and L.P. ends of the cylinder, set half in the bedplate and half in projections from the cylinder on the vertical centre line. These keys enable the cylinder to breathe vertically, but keep the cylinder central sideways under all conditions, and thus compel the expansion (lateral) to take place equally on both sides. The dowels should be made an easy tapping fit, and the holes through the cylinder feet, through which the holding-down bolts pass, should be at least $\frac{1}{4}$ in. bigger in diameter than the bolt, so as to allow the cylinder to expand and move laterally when heated. The bolts, therefore, have to be of special construction; they are known as collar or shoulder bolts, and are shown, together with the corresponding type of stud, in the accompanying sketches. A special washer is always used under the head of the bolt or under the nut of the stud, and it will be seen that when the bolt is tightened hard down on the shoulder, and the length from shoulder to under side of head is just correct, that the cylinder, while definitely held down, can move or expand sideways as required. In order to get the exact length of the bolt, from shoulder to head, the bolt is tightened down with the collar in position, and the amount of slack between the collar and the head is then measured with feeler gauges, and the length from shoulder to head is then reduced by the figure obtained with the feelers, with the exception of two thousandths, which is left on in order to provide a very small clearance between the bolt head and washer, and thus allow the cylinder to expand.

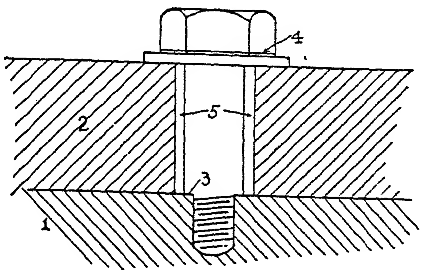


Fig. 6.—Holding-down Shouldered Bolt to allow for Expansion and Contraction of Cylinder Feet relative to Bedplate

1, Bedplate. 2, Cylinder feet. 3, Bolt shoulder. 4, ·002 in. for sliding clearance. 5, Clearance round bolt for expansion of cylinder relative to bedplate.

Before jointing up any steam-pipe, or the valve chest to the cylinder bottom half, they should be carefully examined for any loose material, e.g. nuts, pieces of steel, borings, &c., that may have lodged in the steam passages; in the case of steam-pipes it is very advisable to either draw a heavy chain through them repeatedly, or to tap them all over the external surface with a heavy hand hammer, or to do both, in order to loosen any scale or rust that may have formed inside the pipes, due to the "weathering" of the hard skin on the inside of the pipes. In particular, the steam-nozzles should

be carefully examined, especially the nozzle-box or space behind the nozzles, which appears to be a favourite place for foreign matter to collect. Any foreign matter not removed will be blown through by the steam, and may seriously damage the turbine blading. As a rule, the joints between the steam-chest and the turbine cylinder are dowelled, in the manner shown herewith, in order to definitely fix the position of the steam-chest. The dowels are put in at the joint in order that they can be easily withdrawn or knocked out when the joint is broken. If the dowels are put in at right angles to the joint, as in the other sketch, there is a danger of the dowel being " burned in " by the prolonged action of the heat of the steam, more particularly when the steam is superheated. On the other hand, great care should be taken to see that the dowel used in the joint is made an easy tapping fit after the joint is bolted up tight. If the dowel is too tight, there is a danger of the joint being forced open at the dowel-pin, and thus causing serious steam leakage. A note will be added later, on the making of joints for steam-, water-, and oil-pipes.

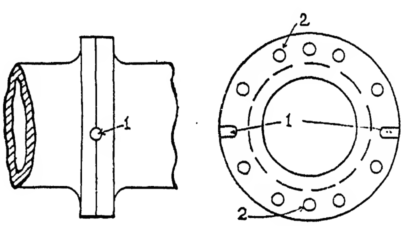


Fig. 7.—Dowel-pins in Joints

1, Dowel-pins drilled radially. Joint can easily be split and dowel-pins removed. 2, Holes for hex-headed dowel-pins at right angles to joint. On high-temperature steam-pipes these dowels are liable to " burn in ", and have to be drilled out, unless they are made a fairly easy fit initially.

Assuming, then, that the nozzles and steam-chest have been carefully examined and cleaned out and jointed up to the bottom half of the cylinder, the next step is to put in position the bottom halves of the stationary diaphragms. Before this is done the outside surface of the diaphragms, which fit into the grooves in the cylinder, should be carefully rubbed over with a little flake graphite to prevent them rusting in in course of time. After the diaphragm bottom halves are in position, the drainage of the cylinder should be tried in order to see that water, condensed steam, &c., cannot collect in the cylinder, and not only cause rapid deterioration of the blading, but also be the cause of the turbine shaft " whipping ", due to the wheels running in water at the bottom. The effects produced in this way are sometimes very serious, and have been disastrous. The best way to test the drainage is to open all drain-cocks and run water from a hose in between the diaphragms, and into all pockets where water may lodge. As a rule, the diaphragms are so arranged that any water in the cylinder automatically drains away to the exhaust end, and thence into the condenser. This is accomplished by the design, or, where necessary, a small hole, say $\frac{3}{8}$ in. diameter, is drilled through the bottom of the diaphragms in an axial direction, the hole being increased at the L.P. stages to $\frac{1}{2}$ or $\frac{5}{8}$ in. diameter. A small quantity of steam blows through this drain hole and keeps the cylinder clear of water, the loss of steam being quite insignificant. Previous to putting the bearings in position, the bottom halves should be carefully scraped and bedded on the journals of the shaft they have to carry. This is done by smearing a

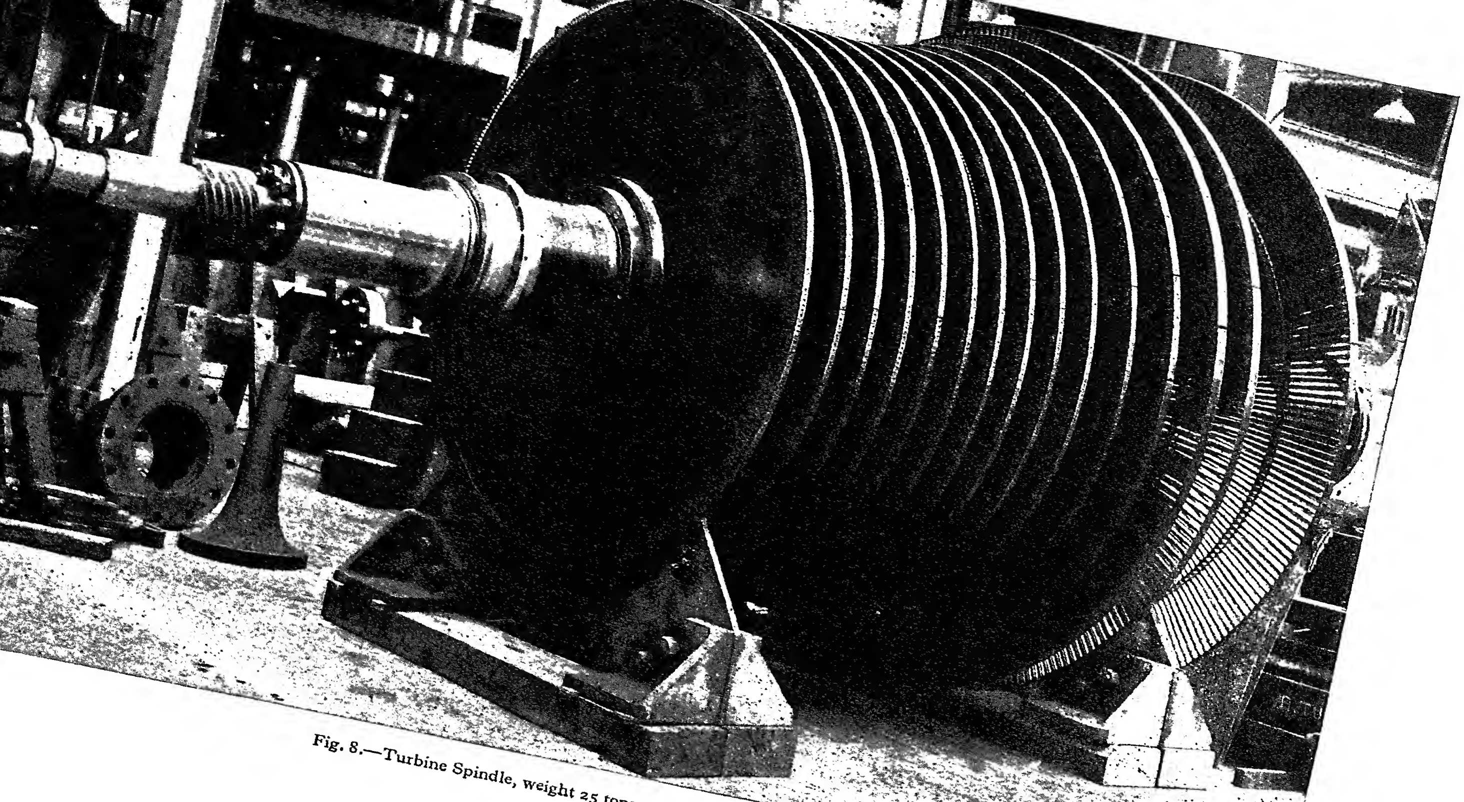


Fig. 8.—Turbine Spindle, weight 25 tons, of 20,000-kw. Turbine

little red lead mixed with thin machine oil on the journal, and then rubbing it uniformly over the journal till almost dry. The bottom half-bearing is then put on the journal and rocked backwards and forwards a few times; the high or " hard " spots of the bearing will be marked with red lead, and must be carefully scraped down with a curved scraper; the red lead should be smeared uniformly over the journal before the bearing is again marked. This process is continued till the bearing is marked pretty uniformly. The top half-bearings are also tried for marking, and the hard spots removed, but the marking process is not carried so far, or is so complete, as in the case of the bottom halves. (An exception is made in the case of bearings for reciprocating plant, where the pressure comes on the top and bottom half-bearings alternately, and the necessity, therefore, exists for the marking and scraping of both halves to be done very carefully.) After all the bearings have been scraped, the bottom halves are put in position in the pedestals or housings, and the centre line, previously used, is again stretched through in order to align the actual bearings.

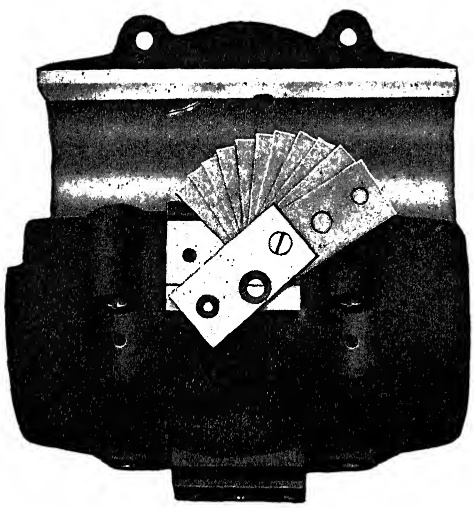


Fig. 9.—Padded Bearings, showing Adjusting Liners behind Steel Pads

The bearings of high-speed turbine plant are invariably provided with means for adjusting the bearing relative to the pedestal or housing, both vertically and horizontally. The vertical adjustment is usually made by means of liners, both at the top and the bottom of the bearing: the adjustment sideways is made either by liners or by two tapered steel wedges on either side. The bearings, also, are frequently made self-aligning by the provision of spherical seatings in the housings, but this degree of self-alignment is slight, and is provided simply to allow the bearings to take up a comfortable position on the journals, and to remove stresses due to slight inaccuracies of alignment, or due to alteration of alignment, caused by stresses in the castings or settling of foundations, &c. One of the most convenient and widely used bearings is the padded bearing, on which there are packets of thin liners at the top, and bottom, and sides, consisting of sheets of steel, varying in thickness from ·005 up to ·025 in., each set of liners being covered by a steel pad, through which screws pass and secure the pad and liners to the bearing. By removing a liner, say ·005 in., from one side pad to the other, the whole bearing is moved over ·005 in.; in the same way the bearing can be raised or lowered by very fine stages.

Before the turbine spindle is put in position, it is advisable to raise the

bottom half-bearings, say $\frac{1}{32}$ in., by means of the bottom pads, previously described; this is a wise precaution to prevent damage to the brass labyrinth packing strips which line the H.P. and L.P. glands, diaphragm collars, &c., to prevent leakage of steam out, or air in. Some oil should be poured over the shaft journals and into the bottom half-bearings; the shaft should then be carefully lowered till resting in the bearings, special care being taken during this lowering operation that the wheels are clear of the fixed diaphragms between them. The thrust block bottom half should then be put in position and wedged up temporarily with wooden wedges, to prevent any axial move-

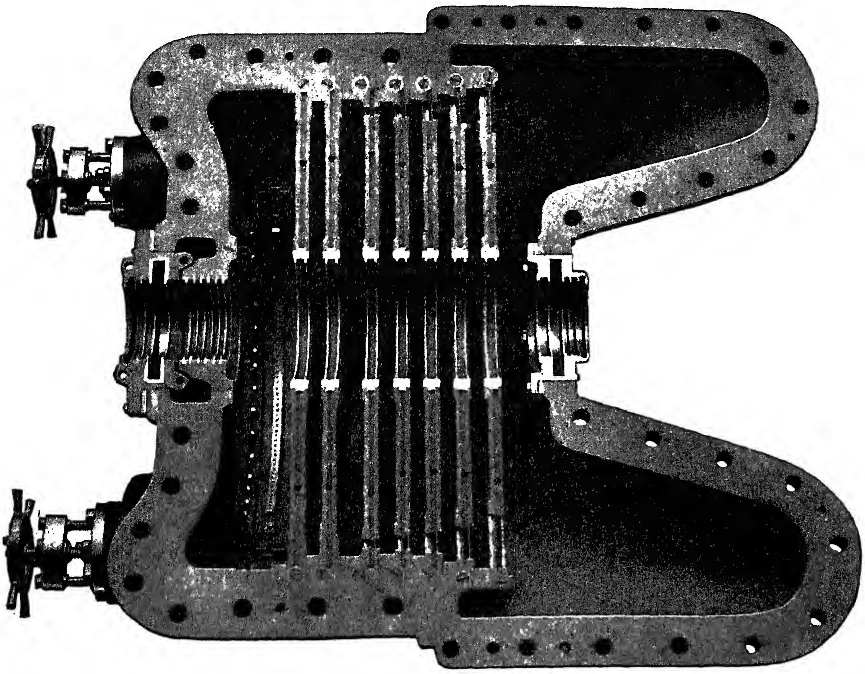


Fig. 10.—Top Half of Turbine Cylinder turned over for fitting of Top-half Diaphragms, Glands, and Nozzles

ment. The shaft and wheels are then slowly revolved by hand, or if necessary by means of the crane pulling on a rope previously wrapped round the shaft. If the brass labyrinth strips are touching the shaft, they will mark the shaft with a fine yellow line. Before lifting the shaft to scrape the labyrinth strips, it is advisable to fix the vertical guide-strips in position to prevent the wheels fouling the diaphragms, and the shaft is then raised and the brass labyrinth strips scraped and sharpened up again where the shaft has rubbed them flat. The shaft is then lowered again into its final central position by previously removing the $\frac{1}{32}$ in. of liners added to the bottom pad under the bearings.

In order to put the half-diaphragms in the top half-cylinder, the latter is turned upside down and the diaphragms then put in position and secured by " keeps " held in by screws. Before the diaphragms are put in position,

any nozzles in the top half should be bolted in position and properly jointed up. The completed top half-cylinder is then turned back into the upright position, and carefully lowered down into place on the bottom half. Guide-rods are usually provided for guiding down the top half, and it is advisable to put strips of sheet metal $\frac{1}{32}$ in. thick and 3 or 4 in. wide at several places round the main horizontal joint. This is done in order to try the spindle for being free before the top half is right down in position. The spindle is then pulled round once or twice by hand or by the crane, and if quite free, the pieces of sheet metal can be removed from the horizontal joint, the weight of the top half being meanwhile taken by the crane. The top half is then lowered right down and the spindle pulled round again. The cover is then finally lifted, and the edges of the brass labyrinth packing strips sharpened up. The setting of the thrust block, which determines the position axially of the turbine spindle, should now be carefully adjusted, and the axial clearances between the wheels and the fixed diaphragms very carefully checked over at both sides of the turbine. A record should be kept of these clearances, and if they are less than the clearances required by the particular type of turbine being erected, it may be necessary to have the fixed diaphragms further machined; special care should also be taken to observe and accurately measure the clearance between the nozzles and the blades on the first wheel.

When the spindle has been finally set, the permanent collars for securing the thrust block in position axially can be machined to the required thickness, and either pinned on to the thrust block by two or three countersunk screws, or left loose and tapped round into position.

Having prepared the main horizontal joint of the turbine cylinder and spread the jointing material uniformly, the top half is lowered into position, dowel- or steady-pins driven in to fix the relative positions of top and bottom half-cylinders, and the bolts through the joint then put in, and either banged up tight with a large spanner and heavy sledge-hammer, or pulled tight with a heavy spanner over the stem of which is passed a piece of heavy pipe several feet long, for additional leverage.

When the supply of steam is available, it is advisable to go round all joints which reach a high temperature under working conditions, and tighten up the bolts after the joint has been heated up. The effect of heat causes the jointing material in the majority of cases to " give ", and this give should be taken up on the bolts through the joint, otherwise the joint will very probably begin to blow in a very short time.

The next operation is to erect the alternator and couple it up to the turbine. In the very great majority of cases the alternator stator is built in one piece, i.e. not split horizontally, the exceptions being few and far between. The advantages of making the stator without a horizontal break are very great, both from the electrical as well as from the mechanical standpoint, so that even the largest alternators are made in one piece. This means, therefore, that the generator rotor has to be threaded through the stator, and as this is an operation which has puzzled many engineers, a description is given of the method employed.

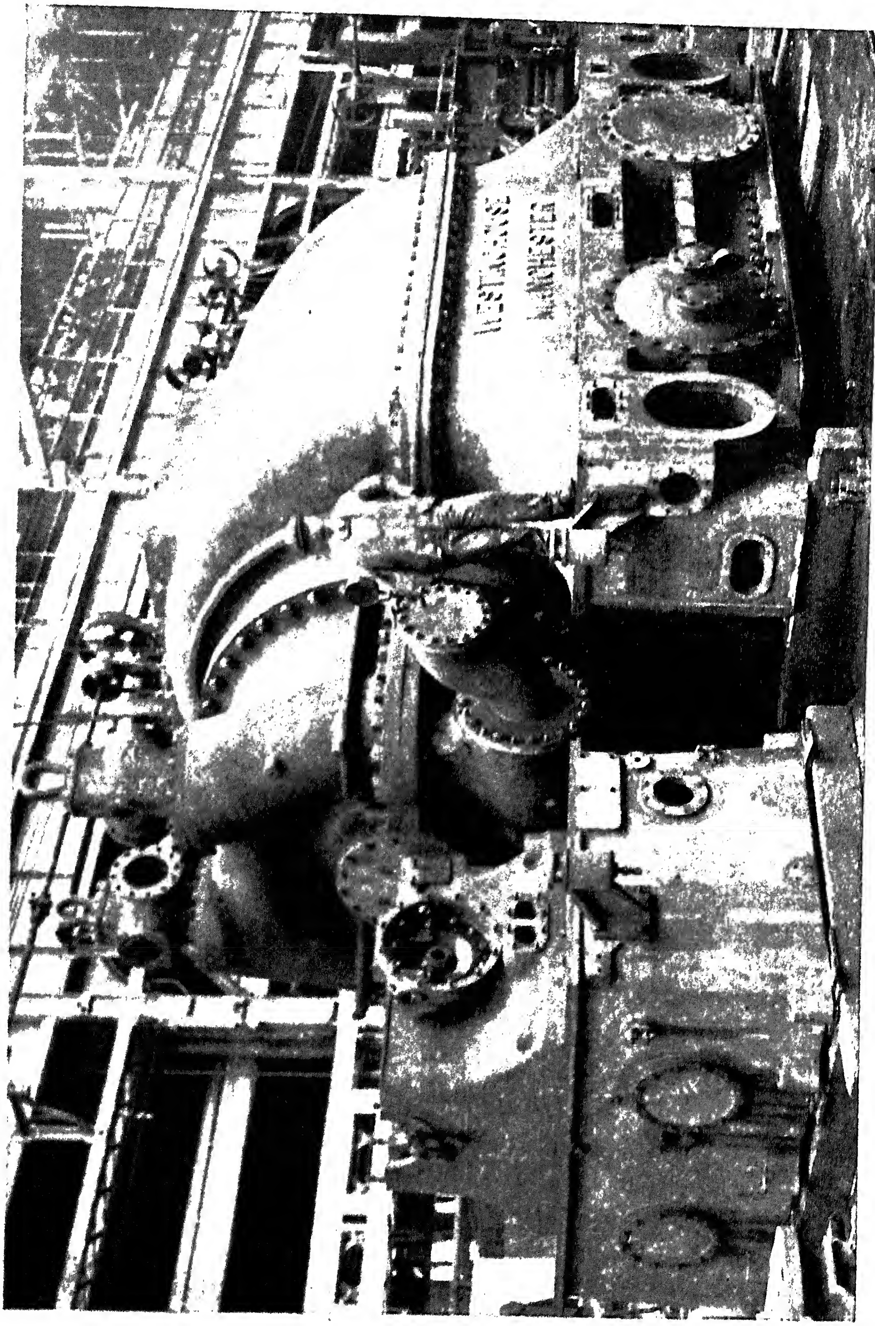
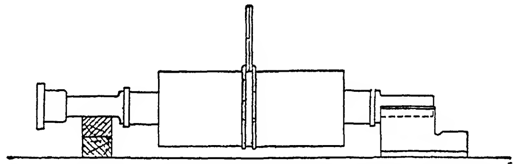


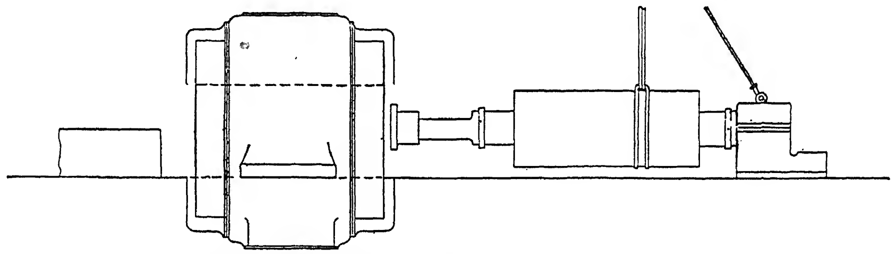
Fig. 11.—20,000-kw, Turbine in course of erection at makers' works

First the generator outboard pedestal is roughly levelled up on the engine-room floor, or elsewhere in case the engine-room floor is not designed to carry heavy weights. The journals of the generator rotor are carefully cleaned, and the top and bottom half-bearings for each end bedded down,

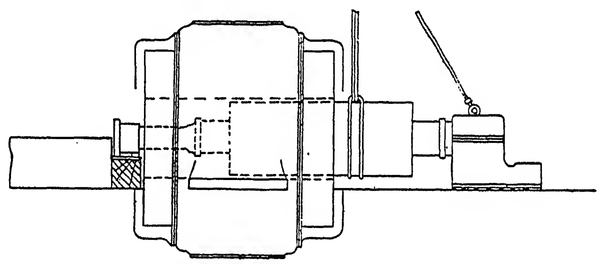
as described previously. The shaft journals are then cleaned, a little oil rubbed round the journals, and the rotor put in position in the outboard



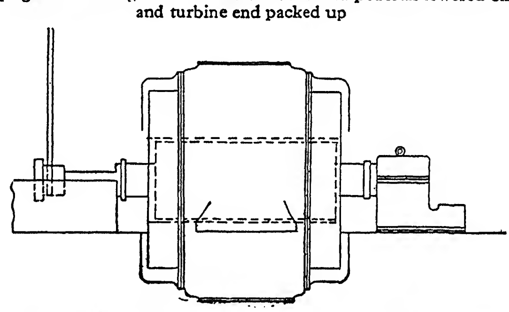
1st position—Rotor with central lift lowered into outboard pedestal and packed up at turbine end



2nd position—Pedestal cover bolted on. Pedestal forms an out-of-balance weight which enables rotor to be slung out of the geometric centre. Chain blocks can be hung on crane hook and help to support pedestal if necessary



3rd position—Sling up against end of generator stator. Outboard pedestal lowered on small steel rollers and turbine end packed up



4th position—Turbine end raised, rotor jacked or pulled on rollers into final position

Fig. 12

pedestal, the other end of the shaft being packed up on baulks of timber, &c., as far as possible dead level. The top half-bearing and pedestal cover are then put in position on the outboard pedestal, but the bolts securing the cover are left about $\frac{1}{32}$ in. slack. The rotor, together with outboard pedestal, is then slung on the crane, care being taken to arrange the sling

(a wire rope is best) in the manner shown. It is obvious that the pedestal forms an out-of-balance weight, which brings the centre of gravity from

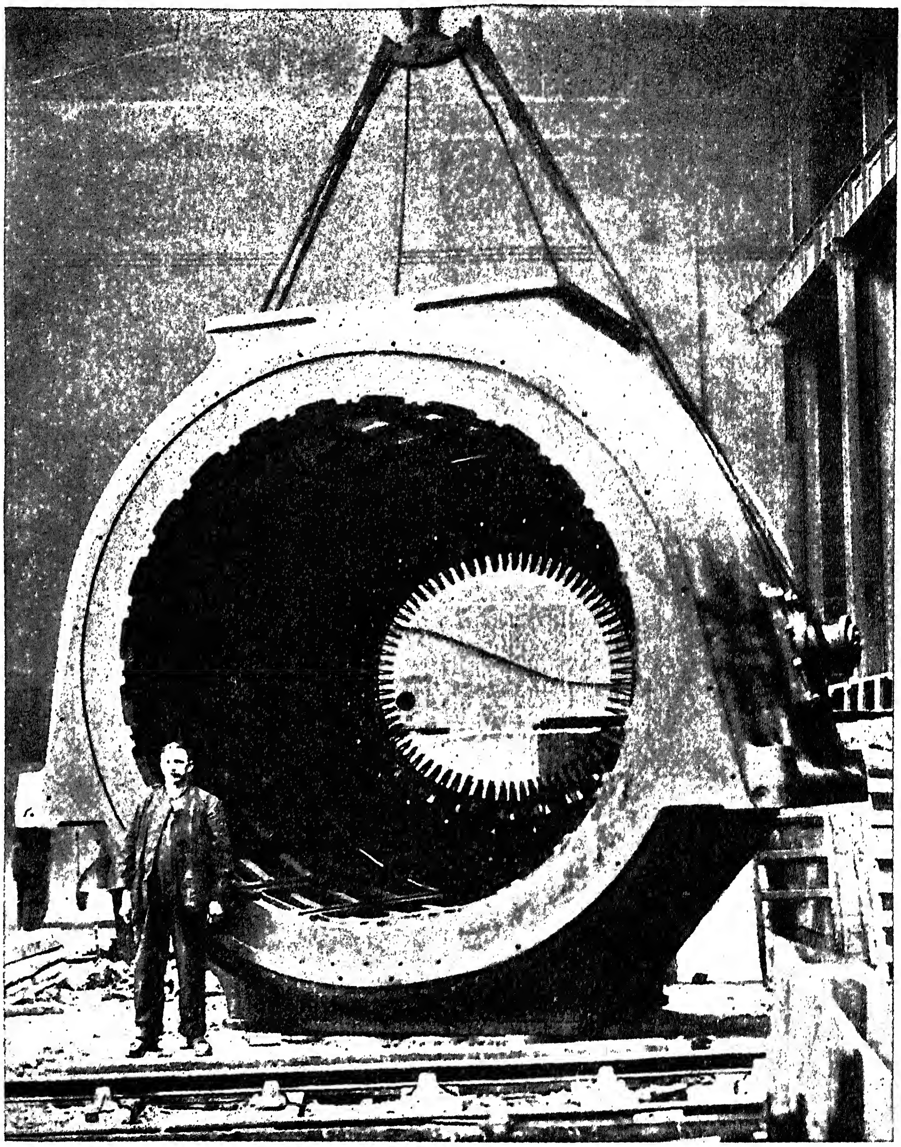


Fig. 13.—Stator Shell of 20,000-kw. Turbo-alternator, single casting, weight 28 tons, showing steel trunnion pins for turning casting on end

the geometrical centre towards the pedestal, and thus leaves one end specially long, as shown in the sketches. Great care must be taken to get the whole piece dead level when hanging on the crane, a spirit-level being used for the purpose, held on the journal or parallel part of the shaft, the point of support

(i.e. where the wire sling grips the rotor) is moved until the balance is obtained. Sometimes, in order to achieve this, it is necessary to hang a set of chain blocks on the crane hook and support the pedestal slightly by tightening up the chain blocks. Having thus got the rotor slung level, it is an easy matter to thread the piece through the stator until the rope sling supporting the rotor, &c., is nearly up against the stator winding. A support of steel beams or baulks of timber should previously have been arranged to support the turbine end of the generator rotor, and the rotor is then carefully lowered; some ten or twelve, or more, steel rollers should be placed under the outboard pedestal, and the latter lowered down on to them. These rollers should be made of $\frac{1}{4}$ in. diameter steel rod, in lengths a little greater than the width of the pedestal. The sling is then removed from the body of rotor, and the turbine end of the rotor shaft is supported by the crane, and a slight endwise pull applied by the crane. The pedestal end will roll on the small rollers, and, when the generator and turbine couplings are together, the generator bearing (turbine end) can be put in position and the rotor lowered into it. It only remains to lift the outboard pedestal end of the rotor with the crane and remove the small rollers. It is the practice nowadays to place a sheet of insulating material, e.g. fuller-board, leatheroid, &c., under the outboard pedestal, and to insulate from the pedestal, by means of insulating tubes and washers, the bolts which hold the pedestal down to the bedplate. This is done to prevent the circulation of stray currents through the rotor shaft, pedestals, and bedplate. Under certain circumstances these stray currents reach high values, and the effect on the generator is to cause pitting of the journals and white-metal bearings, and the breaking up of the oil passing through the bearings, with the formation of acid, which in turn causes further corrosion.

Before closing up the bearings and bolting down the bearing pedestal covers, it is most important that the clearances between the bearing and journal for oil be accurately measured, and if necessary increased to a safe figure, and at the same time the fact be definitely established that the cover is actually binding down the bearing inside it. The white-metal lining of the bearings should be scraped away carefully at the sides (see fig. 15) for a sufficient distance down, so as to leave the actual bearing area—that area contained in an angle of about 120°; this side clearance should not be less than five-thousandths of an inch, and it should be possible to get a feeler gauge down on each side, all along the bearing. The clearance between the top of the journal and the bearing is obtained by putting two or three strands of soft lead wire across the journal and bolting the top and bottom half-bearings tightly together; on opening out again, the lead will be found to have been flattened out to the exact clearance on the top of the bearing, and this thickness can then be accurately measured by a micrometer gauge. This clearance varies with different makers; an average figure is about 1 mil. (·001 in.) per inch of journal diameter, and if necessary the inside of the top half-bearing should be scraped away carefully to obtain the necessary uniform clearance.

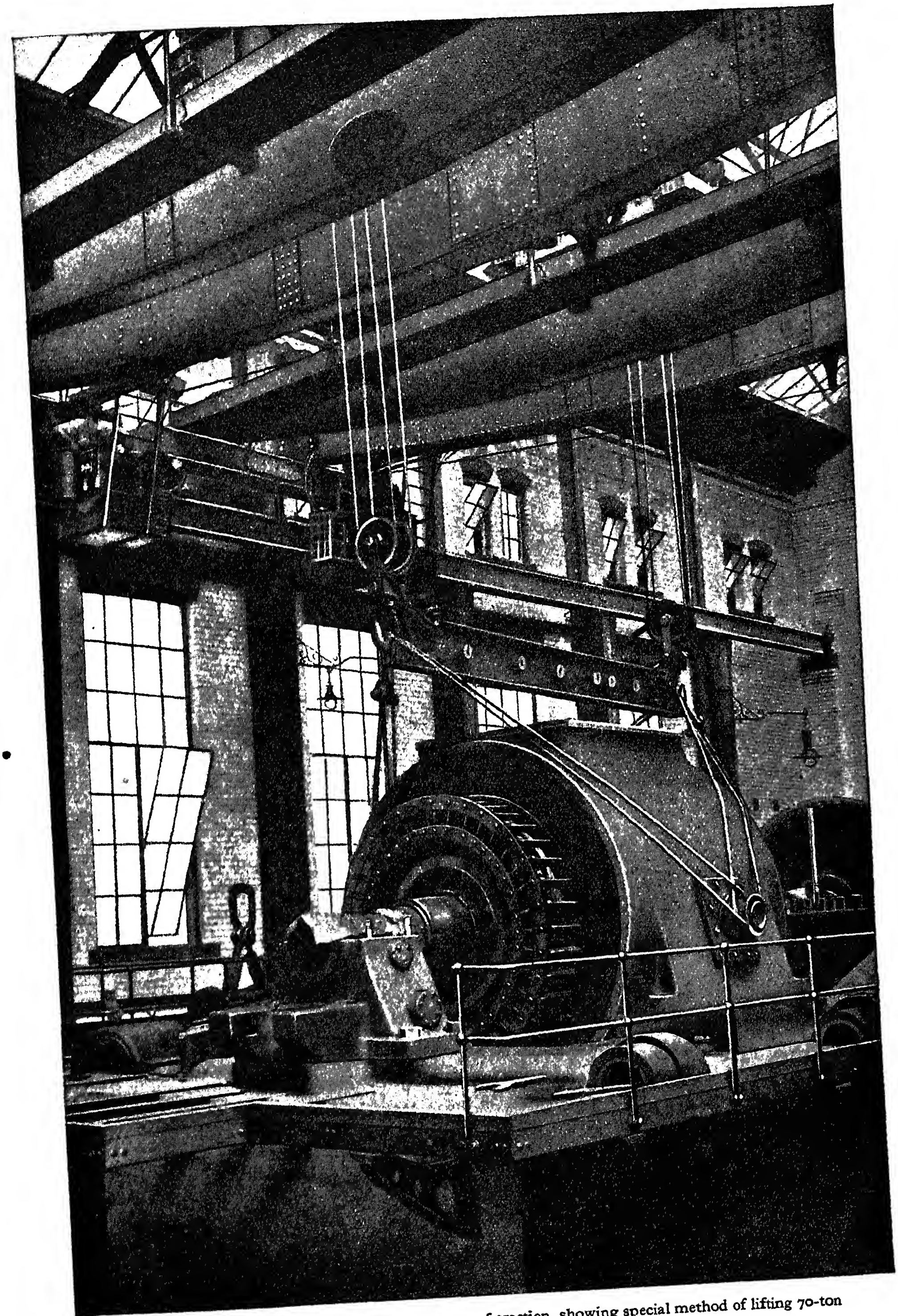


Fig. 14.—20,000-kw. Turbo-generator in course of erection, showing special method of lifting 70-ton stator by two cranes, as neither crane by itself could lift the piece

In order to determine whether the pedestal cover is binding down the bearing, immediately before the cover is put on, a strand or two of soft lead wire is laid across the top pad or outside machined surface of the bearing and the pedestal cover then bolted down; if, on lifting the cover again, the lead wire is not flattened down " to nothing ", additional liners must be put under the top pad, and the test repeated till the desired result is obtained. Unless this precaution is taken, there is liable to be a considerable amount of vibration when the plant is running, and this will result in " hammering " of the bearings and the running of the plant will get rapidly worse. In investigating vibration troubles in high-speed plant, it is always wise to examine the bearings first of all, for clearance and for tightness in the pedestal.

Before finally closing up the bearings, oil should be pumped through the lubricating system in order to see that each bearing is receiving an ample supply of oil. When running up a set such as described above, the utmost care should be taken. As soon as the spindle just starts to move round, the engineer in charge should have a quick run round in order to locate any unusual noises, sign of smoke, or evidence of heat, and be prepared to shut down instantly if necessary. The running-up for the first time frequently takes several hours, during the greater part of which the set is being run at slow speed, which is very gradually increased; this gives any trouble time to show up at lower speed, and gives the man in charge a better chance to avert trouble than if the defect is shown up at full speed.

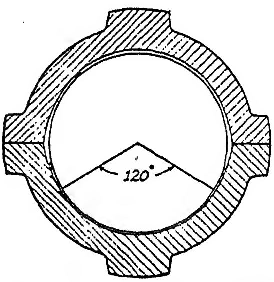


Fig. 15.—Bearing showing Sides scraped away for Oil Clearance

Joints.—In considering the best type of material for making any given joint, while the principal point is the tightness of the joint under working conditions, due regard must be paid to the time and labour involved in breaking the joint, removing the old material, and remaking the joint when such a course becomes necessary, e.g. opening up or dismantling machinery for inspection. There are some materials which make excellent joints, but which are removed only with the very greatest difficulty.

There are a large number of jointing materials on the market to-day, for all of which special advantages are claimed. Some of these materials are in sheets, others in powder or paint, and some in metal, wire, sheet, and net, and nearly every engineer has his own particular method of making any given joint, which he claims is superior to any other method; only a general statement, therefore, can be made as follows:

For Steam-joints (flanged).—The joint faces are very carefully scraped, bedded on a small, portable, plane table, and, before being bolted together, are wiped over very lightly with graphite or some graphitic paint, or even left without any jointing material at all. Alternatively, a Taylor corrugated joint ring is used, which has previously been filled with one or other of the

jointing materials in paint or putty form. For joints in pipes carrying superheated steam, the joint rings should be made of corrugated nickel. Alternatively, a joint ring can be cut from a sheet of jointing material and, before being put in position, painted on both sides with thin graphite paint—or a ring can be cut out of thin copper gauze, and the latter then thoroughly filled with red-lead putty, or other jointing material, before being put in position. For low-pressure steam joints the latter is a favourite method, the addition of a strand or two of lead wire threaded round the gauze adding to its efficiency. In the steam systems of collieries, where low-pressure steam is used without superheat, ordinary rubber joint rings are frequently used with success on systems up to 100 lb. per square inch.

The main joint between the top and bottom halves of a turbine cylinder is usually made by smearing jointing material of the consistency of thick cream on the bottom half, and then adding a strand or two of lead wire at the low-pressure end, and soft copper wire, about No. 27 gauge, at the H.P. end, and then bolting the top half down solidly.

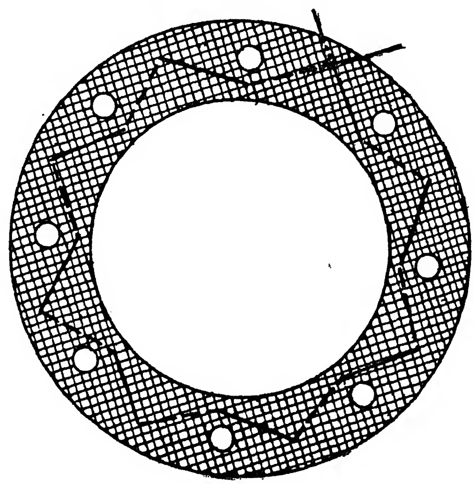


Fig. 16.—Copper Gauze Joint Ring with Lead Wire woven in and filled with Red-lead Putty

It is advisable in the case of all steam-joints, or joints where the temperature is likely to be high, to go round all the bolts in the joint as the temperature is being raised. This is known as "following up" the joint, and it is invariably possible to get an extra turn or half-turn on the bolts and nuts when the joint is heated up. If this is not done, there is a danger of the jointing material being blown out and the joint having to be remade, and in some cases necessitating a shut-down.

For Joints in Water-pipes, rubber insertion is used mostly; the rubber joint ring should be put on dry; some men smear the rubber with tallow or grease, hoping to make a more effective joint, but grease and oil only result in rotting rubber and should therefore not be used.

An excellent joint for flanged water-pipes can be made by a ring of thin copper gauze filled in with red-lead putty, and a strand of lead wire threaded through.

Oil Joints.—Special oil-jointing material in sheet form makes the best joint; this consists of a strong paper boiled in soft soap and caustic soda. Alternatively, ordinary steam jointing material of the asbestos-sheet type is frequently used, but care is taken to paint the joint ring with shellac dissolved in methylated spirit, immediately prior to being bolted up. For large, flat surfaces, soft soap smeared thinly over the surfaces, and a piece of lead wire

laid on, makes an excellent joint. For jointing together large, flat, machined surfaces of condensing plant, red and white lead, thoroughly mixed together into a thin cream by the addition of gold size, is excellent, but it is essential that the ingredients be thoroughly mixed together; the joint can be improved by laying in a strand or two of tubular cotton packing. For very large, flat joints a ribbon of asbestos from 1 to 2 in. broad, laid on a smearing of red and white lead applied to both top and bottom surfaces, makes a very tight joint.

Use of Cranes and Lifting-tackle.—For light lifts, hemp-rope slings are the handiest to use; it is also an advantage to have several lengths of rope of different sizes (not slings), so as to be able to make a sling to any given length, but in tying the two ends together care should be taken to always insert a wooden pin (preferably 3 to 4 in. diameter and tapering down) in the knot; unless this is done it may not be possible to open the knot again, once a heavy weight has been lifted and the knot pulled tight; the taper-pin is easily knocked out and does not lessen the security of the knot.

For heavier lifts, wire-rope slings should be used in preference to chains; the latter are liable to crystallize when in constant use, and eventually snap off short; this is particularly the case in frosty weather. If chain slings are used, they should be annealed at regular intervals, e.g. every three months, by heating to a dull red and allowing to cool slowly. Another objection to chain slings is that the links are liable to press into and damage the machined surfaces of the plant being erected, and in this respect particularly wire-rope slings are much to be preferred, though even wire ropes will press into and indent highly finished surfaces, such as the journals of heavy shafts, and it is usual, therefore, in designing such shafts, to make special provision of space at each end where the lifting slings should be placed.

In lifting a heavy piece the following precautions should be observed:

1. When the crane or lifting-block has been tightened up, so as to just put some tension on the slings, see that the crane ropes are vertical when viewed both from the front and side; unless this is done the piece will swing to one side when lifted, and, in the case of a heavy lift, considerable damage may result.

2. The slinging should always be arranged so that the centre of gravity is below the point of support, i.e. the point or points from which the piece is suspended. If the centre of gravity is above the point of support, the piece may capsize and fall out of the slings when being raised or lowered.

3. If one end of the piece lifts before the other, the sling at the end which lifts first should be lengthened, or the other end shortened. The most convenient way to lengthen a sling is by means of a series of shackles each with removable pin. For shortening a sling, pieces of timber or wooden wedges can be placed between the sling and the piece.

4. Whatever type of sling is used, it should always be protected from damage where it passes over sharp edges, corners, &c.; fillets of sheet iron or thick lead are used, or several thicknesses of sacking.

5. When the piece has been lifted, say, an inch clear, the lifting operation

should be stopped in order to see that the crane brakes are in order, or that the chain lifting-blocks will not run back. The piece should then be raised another inch, in order to see that the crane can start lifting with the load on it. It is unfortunately too often the case that the controlling arrangements of an electrically operated crane will not allow the crane to start against heavy load.

6. The piece should then be lowered an inch, to see that the lowering can be stopped, and that the piece is thus properly under control. By carrying out a few simple precautions of this kind much trouble and damage can be averted, as, if the crane should fail to hold the piece, it can only run down an inch or two at most.

7. When everything is satisfactory, and the brake blocks, &c., adjusted if necessary, the piece can be lifted into position, though care should always be taken when lowering to see that the crane and lifting tackle are not subject to shocks due to suddenly stopping.